Appendix C

Long-term Monitoring Plan

Model Long-term Monitoring Plan for the Lower Fox River and Green Bay, Wisconsin

Prepared for:

Wisconsin Dept. of Natural Resources

♦ **The RETEC Group, Inc.**

RETEC Project No.: WISCN-14414

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Model Long-term Monitoring Plan

Feasibility Study for the Lower Fox River and Green Bay, Wisconsin

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Attachment 2	Draft Report on the Lake Michigan Tributary Monitoring Project
Attachment 3	Cost Estimate for Long-term Monitoring

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List of Acronyms

$\mu g/kg$	micrograms per kilogram
AOC	Area of Concern
ARARs	Applicable or Relevant and Appropriate Requirements
ARCS	Assessment and Remediation of Contaminated Sediments Program
BBL	Blasland, Bouck, and Lee Engineers
bw	body weight
CAD	confined aquatic disposal
CCMA	Center for Coastal Monitoring and Assessment
CDF	confined disposal facility
CENR	Committee on Environmental and Natural Resources
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cm	centimeter
COC	contaminant of concern
COPC	contaminant of potential concern
DAMOS	Disposal Area Monitoring System
DDD	dichlorodiphenyl-dichloroethane
DDE	dichlorodiphenyl-dichhloroethylene
DDT	dichlorodiphenyl-trichloroethane
DOC	dissolved organic carbon
Ecology	Washington State Department of Ecology
ELIZA	enzyme-linked immunosorbent assay
EMAP	Environmental Monitoring and Assessment Program
EP	Estuary Program - San Francisco
EPA	United States Environmental Protection Agency
EROD	ethoxynesorusin-o-deethylase
FDA	Food and Drug Administration
FRG	Fox River Group
FS	feasibility study
g	grams
GAS	Graef, Anhalt, Schloemer and Associates, Inc.
GBMB	Green Bay Mass Balance Study
GLNP	Great Lakes National Program
GLNPO	Great Lakes National Program Office
Hg	mercury
kg	kilogram
LaMP	Lake-wide Management Program
LFR	Lower Fox River

List of Acronyms

LLBdM	Little Lake Butte des Morts
LTMP	long-term monitoring plan
MDEQ	Michigan Department of Environmental Quality
mg	milligrams
mg/kg	milligrams per kilogram
MNA	monitored natural attenuation
MNR	monitored natural recovery
NCP	National Contingency Plan
NEP	National Estuary Program
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NRDA	National Resource Damage Assessment
NS&T	National Status and Trends
OSWER	Office of Solid Waste and Emergency Response
PCB	polychlorinated biphenyl
PSAMP	Puget Sound Ambient Monitoring Program
QA	quality assurance
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RI/FS	remedial investigation/feasibility study
SAIC	Science Applications International Corporation
SF	San Francisco
SMU	sediment management unit
SWQD	Surface Water Quality Division
TBC	To Be Considered
TOC	total organic carbon
TSS	total suspended solids
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WDNR	Wisconsin Department of Natural Resources
wt	weight
WWC	Woodward-Clyde
YOY	young-of-the-year

1 Introduction

This document presents a model long-term monitoring plan for the Lower Fox River and Green Bay feasibility study (FS). In accordance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the National Contingency Plan (NCP), the Wisconsin Department of Natural Resources is conducting a remedial investigation/feasibility study (RI/FS) for the Lower Fox River and Green Bay to address the current risk to human health and the environment and present feasible remedial alternatives. As part of this FS process, EPA has requested that a proposed long-term monitoring plan be developed. The long-term goal of the remediation project will be to reduce the concentrations of polychlorinated biphenyls (PCBs) and other contaminants in fish and invertebrates, thus reducing ecological and human health risk.

The purpose of this long-term monitoring plan will be to verify reduced risk to ecological receptors in the event that selected remedial strategies and outcomes leave residual PCBs or other site contaminants in surface sediments. Environmental monitoring can be defined as a continuing program of modeling, measurement, analysis, and synthesis that predicts and quantifies environmental conditions or contaminants and incorporates that information effectively into decision-making in environmental management (NRC, 1990). This proposed long-term monitoring plan would be implemented for all remedial alternatives including monitored natural recovery (MNR), however, it does not pre-suppose one remedy over another. It serves as a generic monitoring plan that will require modifications and/or additions depending upon the final remedy selection and design. The final plan would likely be determined and negotiated during the design phase.

The Baseline Risk Assessment (ThermoRetec, 2000b) for the Lower Fox River and Green Bay concluded that PCBs, mercury, and DDE pose the greatest long-term risk to human health and the environment. Therefore, long-term monitoring will focus on monitoring these compounds in several ecological media to assess the long-term effectiveness of the remedial alternatives proposed in the FS. For this project, effectiveness is defined as attainment of the long-term remedial action objectives (RAOs) defined for the Lower Fox River and Green Bay FS. Monitoring parameters described in this document include media, frequency, duration, location, and chemical analyses to verify achievement of project goals.

Long-term monitoring begins after completion of remedial actions or after the decision to implement a MNR strategy. However, adequate baseline data will be collected prior to remediation to ensure establishment of a data set comparable to post-remedy measurements.

1.1 Monitoring Plan Development

The proposed long-term monitoring plan was developed after careful review of regional and national monitoring programs, guidance documents related to management of contaminated sediments, case study projects, and scientifically-based recommendations presented by sediment work-groups, regulatory agencies and resource trustees (Sections 2 and 3). A possible list of monitoring options was developed from these documents, and the final list of monitoring elements selected for the Lower Fox River/Green Bay project were screened through five important management factors developed by the National Research Council (NRC). These factors were defined by the NRC as essential rudiments of a well-defined and implementable monitoring plan (Section 4). The potential monitoring elements retained from the NRC-based screening process were categorized into their intended use for verification of the project remedial action objectives. A detailed description of the monitoring strategy for each element includes the media, sampling location, frequency, sample type, approximate number of samples, and duration developed for each RAO (Section 5).

1.2 Document Organization

This document is organized into five major sections summarized as:

- Section 1 - background, purpose, and scope;
- Section 2 - a review of national, regional, and local monitoring programs;
- Section 3 - a review of applicable guidance documents used on contaminated sediment projects;
- Section 4 - selection of a monitoring plan strategy; and
- Section 5 - the proposed long-term monitoring plan for the Lower Fox River/Green Bay remediation project.

Attachment 1 located at the end of the main text provides additional detail on selected monitoring programs. Attachment 2 presents a draft report of the ongoing Lake Michigan Monitoring Project for the Fox-Wolf River Basin. The Sediment Technologies Memorandum (Appendix B of the FS) also provides useful information on the monitoring programs and lessons learned for site-specific remediation projects that include dredging, capping, and monitored natural recovery alternatives. Attachment 3 presents a cost estimate for the Lower Fox River and Green Bay monitoring program. Labor, equipment, and analytical costs are estimated per sampling event year.

1.3 Background

Background describes historical sources, status of fish and waterfowl consumption advisories, and contaminants of concern (COCs) carried forward for long-term monitoring. The RAOs and exit criteria are also defined in the purpose, goals, and scope subsections.

1.3.1 Historical Sources

An estimated 190,000 kilograms (kg) (418,000 pounds) of PCBs were released into the Fox River and Green Bay between 1954 and the present, mostly during the production of carbonless copy paper by paper mills located along the Lower Fox River (ThermoRetec, 2000a). It is estimated that by 1971 (when use of PCBs in carbonless paper manufacturing ceased), over 98 percent of the PCBs present within the Lower Fox River had been introduced into the system and a portion of these PCBs settled into the river sediments.

The PCB concentrations detected in site sediments along the entire river ranged from 0.34 to 710,000 micrograms per kilogram (μg/kg) with an average sediment concentration of 9,496 μg/kg (median of 1,700 μg/kg) (ThermoRetec, 2000a). Mercury concentrations detected in sediment samples from the river and bay ranged from 0.01 to 9.82 mg/kg with an approximate average sediment concentration of 1.27 mg/kg in the river and 0.22 mg/kg in the bay. Presence of DDT and its metabolites in Green Bay stem from agricultural activities along the shores of Green Bay and its tributaries. DDE concentrations detected in site sediments ranged from 1.9 to 22 mg/kg in the Lower Fox River with an average sediment concentration of 5.54 mg/kg. DDE was not detected in Green Bay sediments, but was detected in several Green Bay fish at adverse risk levels.

1.3.2 Consumption Advisories

Due to the elevated levels of PCBs detected in fish tissue from the Lower Fox River and Green Bay, the Wisconsin Department of Natural Resources (WDNR) issued consumption advisories in 1976 and 1987 for fish and waterfowl, respectively; Michigan issued fish consumption advisories for Green Bay in 1977. General fish consumption advisories are currently in effect for seven species of fish located in the Lower Fox River from Little Lake Butte des Morts (LLBdM) to the De Pere dam, 13 species of fish located from the De Pere dam to the mouth of

Green Bay (WDNR, 2000), and at least 11 species of fish located in Green Bay (MDEQ, 2000) for PCBs (Tables 1-1 and 1-2).

In 1984, Wisconsin initiated its wildlife contaminant monitoring program. Results of the monitoring program indicated that elevated PCB concentrations were present in waterfowl species harvested by sportsmen from Green Bay. Wisconsin then developed procedures for issuing consumption advisories for waterfowl, and issued its first waterfowl consumption advisory for mallard ducks in 1987 (Table 1-3). The advisory has remained in place every year. The advisories are issued each year in the annual hunting guide distributed by the WDNR (Stratus, 1999). WDNR adopted the federal Food and Drug Administration (FDA) threshold level for poultry of 3 milligrams per kilogram (mg/kg) wet weight PCBs on a fat basis.

1.3.3 Contaminants of Concern

Contaminants of potential concern (COPCs) to human and ecological receptors in the Lower Fox River and Green Bay were identified in a Screening Level Risk Assessment for the Lower Fox River (RETEC, 1998) and include: PCBs (total and coplanar congeners), dioxins and furans, DDT and its metabolites (DDE, DDD), dieldrin, and heavy metals (arsenic, lead, and mercury). This COPC list was further delimited in the Baseline Risk Assessment (ThermoRetec, 2000b) to a final list of contaminants of concern (COCs) which include: PCBs (total and coplanar congeners), mercury, and DDE. PCBs, mercury, and DDE are carried forward in the FS and the long-term monitoring plan.

PCBs in the Lower Fox River pose a potential threat to human health and ecological receptors due to their tendency to sorb to sediments, persist in the environment, and bioaccumulate in aquatic organisms (EPA, 1999a). Organochlorine contaminants (i.e., DDE and PCBs) are known to adversely effect the reproductive rates of local bald eagle populations nesting along Green Bay (Dykstra and Miller, 1996). In Green Bay, DDE has been identified as a significant risk factor to local bird populations linking DDE concentration measured in tissue to reproductive success (Custer *et al.*, 1999). Remedial alternatives were developed in the FS to address risks associated with these COCs. In summary, this long-term monitoring plan will include chemical analyses of PCBs, mercury, and DDE in sediments, surface water, and resident bird, fish, and invertebrate populations.

1.4 Purpose and Goals

The purpose of any long-term monitoring plan for a contaminated sediment remediation project should be the protection of human health and the environment.

The purpose of this document is to review relevant sediment monitoring programs, and guidance documents to help formulate a scientifically-based long-term monitoring plan for the Lower Fox River and Green Bay RI/FS process founded on precedent, implementability, appropriateness, and long-term goals. The long-term monitoring program will be designed to verify achievement of, or progress towards, the RAOs for the Lower Fox River and Green Bay. The program will also be consistent with the long-term goals of the Lake Michigan Lake-wide Management Plan (LaMP) (EPA, 2000a).

The goals of the Lower Fox River and Green Bay long-term monitoring plan can be summarized as follows:

- To verify achievement of, or progress towards, the project remedial action objectives (defined below);

- To determine the magnitude of residual risk by collecting fish, bird, and invertebrate tissue data and monitoring the reproductive viability of birds in the project area;

- To determine if suitable mink habitat exists along the shorelines of the Lower Fox River and Green Bay and potentially use this baseline data as a launching point for future mink population surveys.

- To design an effective and technically sound data collection plan that can verify reduced risk and protection of human health and the environment in order to lift fish and waterfowl consumption advisory restrictions over time;

- To formulate clear goals and procedures for the project that will build upon the existing 20-year database and improve sampling consistency and analysis between collection efforts;

- To utilize and continue, to the extent practicable, existing state and federal monitoring programs ongoing in the Lower Fox River and Green Bay; and

- To recognize the long-term goals of the (LaMP).

1.4.1 Project Remedial Action Objectives

For the Lower Fox River and Green Bay contaminated sediment project, five RAOs were defined in the draft FS document (ThermoRetec, 2000c). The primary routes of exposure to human receptors and the measurement endpoints used to verify the condition of ecological receptors for each RAO were defined in the draft Baseline Risk Assessment (ThermoRetec, 2000b). They include:

- **RAO 1 -** Achieve, to the extent practicable, surface water quality criteria throughout the Lower Fox River and Green Bay.

  Primary routes of exposure for surface water to human and ecological receptors are dermal contact with surface water, or incidental ingestion of surface water. Measurement endpoints will be surface water quality.

- **RAO 2 -** Protect humans who consume fish from exposure to COCs that exceed protective levels.

  The primary route of exposure for PCBs and mercury to human receptors identified in the Baseline Risk Assessment (ThermoRetec, 2000b) is direct ingestion of fish or waterfowl. Measurement endpoints will be edible fish and bird tissue.

- **RAO 3 -** Protect ecological receptors from exposure to COCs above protective levels.

  The primary routes of exposure for PCBs, mercury, and DDE to ecological receptors is bioaccumulation and biomagnification from the sediments up through the aquatic food web. Measurement endpoints will include bird, fish and invertebrate tissue, mink habitat, and reproductive viability of local bird populations. Surface sediment samples will also be collected to verify the reduced exposure pathway.

- **RAO 4 -** Reduce transport of PCBs from the Lower Fox River into Green Bay and Lake Michigan.

  The primary mechanism of concern for PCB transport to Green Bay is by storm events or scour effects that significantly increase the sediment bedload and resuspend contaminated sediments that are buried under surficial layers of clean sediment. Measurement endpoints will be surface water and surface sediment quality.

- **RAO 5 -** Minimize the downstream movement of PCBs during implementation of the remedy.

  The primary concern for contaminant releases during active remediation is resuspension of dredged or capped material and downstream transport. This RAO is a short-term objective and is not included in the long-term monitoring plan.

More specifically, the project expectations can be placed on an approximate time line as follows:

- Remediation will be completed within 10 years;

- The sport fish consumption advisories will be lifted within 10 years after remediation (in 20 years); and

- The fish consumption advisories for the general population will be lifted within 30 years after remediation (in 40 years).

1.4.2 Exit Criteria from Monitoring Efforts

The duration of long-term monitoring is expected to last 40 years from the onset of an implemented remediation remedy, including the no action or monitored natural recovery option for the Lower Fox River and Green Bay. Long-term monitoring may be discontinued if decision-making evaluations show that the "exit criteria" for the project have been achieved or that meaningful change has occurred as a result of the remedy. The exit criteria for each remedial action objective can be defined as a numeric or action-related threshold value designed to protect human health and the environment. Attainment of a threshold value must be evaluated before exiting the monitoring program. The exit criteria for this FS are described below.

Proposed exit criteria for the Lower Fox River and Green Bay (RAOs are considered achieved when):

- **RAO 1 -** PCBs measured in surface waters are at or below background levels in Lake Winnebago.

- **RAO 2 -** The fish and waterfowl consumption advisories for the Lower Fox River and Green Bay are removed.

- **RAO 3 -** The levels of PCBs, mercury, and DDE fall below the levels known to effect ecological communities;

  - Whole body PCB, mercury, and DDE levels in resident fish fall below the levels known to effect reproduction;

  - Whole body PCB, mercury, and DDE levels in resident fish-eating birds fall below levels known to cause reproductive dysfunction;

  - Levels of PCBs and mercury in site sediments fall below levels known to effect benthic communities;

  - Bald eagle reproduction along the Lower Fox River and Green Bay consistently achieve levels observed for inland eagle nests in Wisconsin and Michigan; and

  - Total PCB and mercury levels in resident eagle eggs fall to levels observed in background samples.

- **RAO 4 -** Mass balance calculations demonstrate the PCB loads exported from the Lower Fox River to Green Bay, or from Green Bay to Lake Michigan, are equal to input sources external to the river/bay system (e.g., atmospheric deposition).

- **RAO 5 -** (Not included as part of the long-term monitoring plan.) This objective will be assessed during development of active remediation work plans.

1.5 Scope

Before developing a long-term monitoring plan for the Lower Fox River and Green Bay RI/FS project, a review of national and regional monitoring programs and guidance documents was needed to determine a scientifically-based approach with precedent in other regulatory programs. The scope of the review included the following:

- **National and Regional Monitoring Programs.** A review of national and regional monitoring programs describing the types of monitoring elements used to determine current site conditions and environmental impacts to valued receptors. Programs selected were some of largest and most comprehensive monitoring programs currently in operation throughout the United States.

- **Site-specific Remediation Projects.** A review of site-specific sediment remediation projects conducted throughout the United States, Canada, Europe, and Asia, describing the types of monitoring conducted at each site. Projects were selected from a variety of different aquatic systems (lake, river, marine, estuary) with a variety of different implemented remedies (dredging, capping, and MNR) with the intent of presenting a cross section of different physical constraints, receptors, and remediation goals. Discussions and findings are presented in Appendix B, Sediment Technologies Memorandum.

- **Wisconsin and Michigan State Monitoring Programs.** A discussion of long-term monitoring programs currently conducted in Wisconsin and Michigan describing the appropriate regional indicators of biological health (e.g., fish tissue concentrations, bird reproduction). The review focused on fish tissue sampling used for updating the consumption advisories.

- **Guidance Documents.** A review of relevant guidance documents pertaining to the remediation, management, and monitoring of contaminated sediments. This review summarized the perspective and level of expectations by regulatory agencies for the protection of human health and the environment. The goals of this review were to increase consistency between monitoring programs and sites, optimize efforts and resources, focus our ability to detect changes in biological health over time, and support the implementation of national monitoring programs.

- **Recommendations Used for Final Selection of a Monitoring Strategy.** The NRC reviewed numerous reports and monitoring programs related to the management of contaminated sediments. They evaluated the major policy and technical limitations of existing monitoring programs. Based on their review, they developed a conceptual model for the design and implementation of monitoring programs and defined the role of monitoring in marine environmental management. Several management factors were developed to ensure an adequately designed monitoring program. These factors were used to select appropriate monitoring elements (i.e., sediment chemistry, fish tissue chemistry, surface water chemistry, benthic abundance) for the Lower Fox River and Green Bay project. Recommendations put forth by other regulatory groups regarding the management of contaminated sediments are also discussed.

Based upon this review of current monitoring programs, guidance documents, and recommendations, a proposed long-term monitoring plan was developed for the Lower Fox River and Green Bay (presented in Section 5). The proposed approach will be used to refine the expectations and implementability of monitoring measurements, to help determine the costs associated with each alternative, and to coordinate efforts early on with local, regional, and state agencies. Early coordination between different interest groups will help integrate data management needs, optimize use of available resources, and establish useful baseline data sets that will be comparable spatially and temporally with post-project sampling events.

As discussed in other sections of the FS, monitoring of a sediment remediation project is grouped into five categories:

1. Pre-action monitoring prior to remediation to establish baseline conditions (sediment, water, tissue);

2. Monitoring during implementation (water, air);

3. Post-verification monitoring to verify completion of a remedy (sediment);

4. Construction monitoring of containment facilities to verify continued source control (sediment, water); and

5. Long-term monitoring to verify effectiveness of the remedy and attainment of the project RAOs (sediment, water, tissue).

This long-term monitoring plan focuses primarily on Category 5, post-remediation sampling events to verify achievement. Construction monitoring is independent of the long-term monitoring plan (LTMP) and will be designed specifically for disposal sites (i.e., CADs, CDFs, or sand caps). Implementation monitoring pertains to water and air quality monitoring during dredging and capping activities and is not included in the LTMP. However, an adequate baseline data set will be necessary to draw comparisons with post-remedy data. Therefore, this proposed LTMP also applies to categories 1, 2, and 3 for development of a comprehensive baseline data set spanning 10 years. Sample media will include a combination of sediment, water, and tissue for all sampling events.

Table 1-1 Wisconsin Fish Consumption Advisories for the Lower Fox River and Green Bay

Water Body/Fish Species	Unlimited	Limit One Meal/Week	Limit One Meal/Month	Limit One Meal/2 Months	Do Not Eat
Fox River from Little Lake Butte des Morts to De Pere Dam					
Carp					all sizes
Northern Pike			all sizes		
Smallmouth Bass			all sizes		
Walleye			all sizes		
White Bass			all sizes		
White Perch			all sizes		
Yellow Perch		all sizes			
Fox River from De Pere Dam to Mouth					
Black Crappie			less than 9"	larger than 9"	
Bluegill			all sizes		
Carp					all sizes
Channel Catfish					all sizes
Northern Pike			less than 25"	larger than 25"	
Rock Bass			all sizes		
Sheepshead			less than 10"	10"–13"	larger than 13"
Smallmouth Bass				all sizes	
Walleye			less than 16"	16"–22"	larger than 22"
White Bass					all sizes
White Perch				all sizes	
White Sucker				all sizes	
Yellow Perch			all sizes		
Green Bay South of Marinette and Its Tributaries (except the Lower Fox River)					
Brown Trout			less than 17"	17"–28"	larger than 28"
Carp					all sizes
Channel Catfish				all sizes	
Chinook Salmon			less than 30"	larger than 30"	
Northern Pike		less than 22"	larger than 22"		
Rainbow Trout			all sizes		
Smallmouth Bass			all sizes		
Splake			less than 16"	16"–20"	larger than 20"
Sturgeon					all sizes
Walleye			less than 17"	17"–26"	larger than 26"
White Bass					all sizes
Whitefish				all sizes	
White Perch				all sizes	
White Sucker			all sizes		
Yellow Perch		all sizes			

Source: State of Wisconsin, 2000.

Table 1-2 Michigan Fish Consumption Advisories for Green Bay

▲ Unlimited consumption.
● One meal per month
◆ Do no eat these fish.
▼ One meal per week.
■ Six meals per year.

			General Population									Women and Children								
			Length (inches)									Length (inches)								
Water Body	**Species**	**Contaminant(s)**	6–8	8–10	10–12	12–14	14–18	18–22	22–26	26–30	30+	6–8	8–10	10–12	12–14	14–18	18–22	22–26	26–30	30+
Lake Michigan Watershed - All other locations refer to general advice.																				
Green Bay # (South of Cedar River applies to Michigan waters including Menominee and Cedar rivers below first dam. See also **Lake Michigan North of Frankfort**.)	Brown Trout	PCBs			▼	▼	▼	◆	◆	◆	◆			●	●	■	◆	◆	◆	◆
	Burbot	PCBs	▲	▲	▲	▲	▲	▲	▲	▲	▲	▼	▼	▼	▼	▼	▼	▼	●	●
	Carp	PCBs	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
	Channel Catfish	PCBs				▼	▼	▼	▼	▼	▼				■	■	■	■	■	■
	Chinook Salmon	PCBs			▲	▲	▲	▲	▲	▲	▲			●	●	●	●	●	●	●
	Lake Trout	PCBs			▲	▲	▲	▲	▼	▼	▼			●	●	●	●	●	■	■
	Longnose Sucker	PCBs	▼	▼	▼	▼	▼	▼	▼			■	■	■	■	■	■	■		
	Northern Pike	PCBs							▲	▲	▲							●	●	●
	Rainbow Trout	PCBs			▲	▲	▲	▲	▲	▲	▲			●	●	●	●	●	●	●
	Smallmouth Bass	PCBs, Mercury					▲	▼	▼	▼						●	●	●	●	
	Splake	PCBs			▼	▼	▼	◆	◆	◆	◆			●	●	■	◆	◆	◆	◆
	Sturgeon	PCBs									◆									◆
	Walleye	PCBs, Mercury					▲	▼	▼	◆	◆					●	■	■	◆	◆
	White Bass	PCBs	◆	◆	◆	◆	◆	◆				◆	◆	◆	◆	◆	◆			
	Whitefish	PCBs	▲	▲	▲	▲	▲	▲	▲	▲	▲	■	■	■	■	■	■	■	■	■
	White Perch	PCBs	◆	◆	◆	◆						◆	◆	◆	◆					
	White Sucker	PCBs	▲	▲	▲	▲	▲	▲	▲	▲	▲	●	●	●	●	●	●	●	●	●
	Yellow Perch	PCBs	▲	▲	▲	▲	▲	▲				▼	▼	▼	▼	▼	▼			

Table 1-3 Wisconsin Waterfowl Consumption Advisory

Location	Species	Health Advisory Recommendations	Date
Lower Fox River and Lower Green Bay			
Lake Winnebago downstream through Little Lake Butte des Morts (LLBdM) to the city of Kaukauna	Mallard duck	Remove all skin and visible fat before cooking. Discard drippings or stuffings because they may retain fat that contains PCBs.	1987 to present
De Pere dam downstream to the river mouth and includes lower Green Bay south of line from Point au Sable west to the west shore of Green Bay	Mallard duck	Same.	1987 to present

Source: WDNR annual hunting pamphlets. Latest listing year 2000.

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2 Review of National, Regional and State Monitoring Programs

Numerous long-term monitoring programs were reviewed to inventory monitoring elements commonly used in national, regional, and local programs. Two national programs (EMAP, NOAA NS&T) were selected to represent comprehensive national programs focused on assessing the conditions of natural aquatic ecosystems of the United States. Four regional programs (Puget Sound, San Francisco, Great Lakes, and East Coast) were selected to represent progressive and comprehensive regional programs established to understand the human impacts on aquatic resources and to improve the management of these resources. Local and/or state long-term monitoring programs currently in place for the Lower Fox River and Green Bay were also reviewed, consisting primarily of fish tissue sampling for consumption advisory monitoring.

In addition, numerous site-specific contaminated sediment projects were reviewed in the Sediment Technologies Memorandum to document monitoring parameters selected for verification of dredging, capping, and monitored natural recovery remediation alternatives under approval of the Environmental Protection Agency (EPA) and/or state-led agencies (Appendix B of the FS).

The purpose of identifying and reviewing these programs was to point out the recurrence of certain environmental quality measurements in a majority of scientifically based and peer-reviewed programs focused on monitoring the remediation and/or condition of contaminated sediments. Some of the similarities among the national and regional programs in terms of measuring environmental quality are presented in Table 2-1. Table 2-2 summarizes the monitoring elements utilized for site-specific sediment remediation projects. Table 2-3 is a summary of the fish species, including size class and quantity, included in the State of Wisconsin annual fish sampling program for the consumption advisories. Tables 2-4 through 2-7 summarize the distribution and the quantity of existing data collected from the Lower Fox River and Green Bay over time. Detailed descriptions for many of these monitoring programs can be found in Attachment 1 - National and Regional Monitoring Programs and Appendix B of the FS - Sediment Technologies Memorandum.

2.1 National Monitoring Programs

Two of the most comprehensive national monitoring programs include the EMAP and NOAA NS&T programs, which are collecting data on the physical and chemical characteristics of sediments, the bioavailability of contaminants, levels of contaminant residues in the tissues of aquatic organisms, and the health of benthic communities (EPA, 1999a). Each program is briefly described below. Elements of each monitoring program are described in Attachment 1.

2.1.1 EPA Environmental Monitoring and Assessment Program (EMAP)

EMAP is a research program used for developing the tools necessary to monitor and assess the status and trends of national ecological resources. EMAP's goal is to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of ecological condition. These assessments will be used to forecast future risks to the sustainability of our natural resources (EPA, 2000c). EMAP's research supports the National Environmental Monitoring Initiative of the Committee on Environment and Natural Resources (CENR).

The objectives of EMAP are to advance the science of ecological monitoring and ecological risk assessment, guide national monitoring with improved scientific understanding of ecosystem integrity and dynamics, and demonstrate the CENR framework through large regional projects. EMAP will develop and demonstrate indicators to monitor the condition of ecological resources, and investigate multi-tier designs that address the acquisition and analysis of multi-scale data including aggregation across tiers and natural resources.

2.1.2 NOAA National Status and Trends Program (NOAA NS&T)

In 1984, NOAA initiated the NS&T Program to determine the current status of, and to detect changes in, the environmental quality of our Nation's estuarine and coastal waters. The NS&T Program is managed by the Center for Coastal Monitoring and Assessment (CCMA) in NOAA's National Ocean Service. The NS&T: 1) conducts long-term monitoring of contaminants and other environmental conditions at more than 350 sites along United States coasts, 2) studies biotic effects intensively at more than 25 coastal ecosystems, 3) partners with other agencies in a variety of environmental activities, and 4) advises and participates in local, regional, national, and international projects related to coastal monitoring and assessment (NOAA, 2000).

The NS&T Program is comprised of several projects, including: the Benthic Surveillance Project, the Mussel Watch Project, the Quality Assurance Project, Historic Trends, the Sediment Coring Project, the Specimen Banking Project, Sediment Toxicity Surveys, Biomarkers, Environmental Indices, and regional assessment and topical reports.

2.2 Regional Programs

The regional monitoring programs reviewed were intended to provide information regarding a variety of programs extending from the west coast (Puget Sound Ambient Monitoring Program [PSAMP] and San Francisco Bay Estuary Program), to the Great Lakes (Great Lakes National Program Office [GLNPO]), and the East Coast (Disposal Area Monitoring System [DAMOS] disposal site program). Each program is briefly described below. Elements of each monitoring program are described in Attachment 1.

2.2.1 Puget Sound Ambient Monitoring Program (PSAMP)

As part of the PSAMP, the Washington State Department of Ecology has collected sediment samples throughout Puget Sound, Hood Canal, and the Strait of Georgia from 1989 through 1995 (Ecology, 2000). The PSAMP was implemented for the following purposes:

- Provide a record of the condition of Puget Sound sediments.
- Aid in the identification of reference sites/values.
- Provide data for use by researchers concerned with sediment quality.

The following are specific objectives to be addressed by the PSAMP:

- Collect baseline and long-term data on Puget Sound sediments and macro-invertebrate communities in uncontaminated and contaminated areas.

- Identify areas of Puget Sound that are accumulating toxic chemicals.

- Assess the potential sediment toxicity resulting from accumulating toxic chemicals.

- Evaluate the condition of Puget Sound benthic macro-invertebrate communities in relation to the concentration of toxic chemicals in sediments.

- Document both natural and anthropogenic changes to sediment quality.

The current PSAMP program consists of both temporal (long-term) monitoring and spatial monitoring.

2.2.2 San Francisco Bay Estuary Program

The San Francisco Bay Estuary Program is part of the National Estuary Program (NEP) which was established in 1987 by amendments to the Clean Water Act to identify, restore, and protect nationally significant estuaries of the United States (National Estuary Program, 2000). The NEP targets a broad range of issues and engages local communities in the process. The program focuses not just on improving water quality in an estuary, but on maintaining the integrity of the whole system—its chemical, physical, and biological properties, as well as its economic, recreational, and aesthetic values.

To assist in coordinating research and monitoring programs, the San Francisco Estuary Project has fostered the development of a Regional Monitoring Strategy (Monitoring Strategy). The primary purposes of the Monitoring Strategy are to:

- Provide information to assess the effectiveness of management actions that have been taken to improve conditions in the estuary and to protect its resources.

- Evaluate the ecological "health" of the estuary and enhance scientific understanding of the ecosystem.

Implementation of the Monitoring Strategy will strengthen the Estuary Project's continuing effort to promote environmentally sound management of the bay and delta. The Monitoring Strategy will improve the ability to define human-induced stresses on the estuary, help to assess the effectiveness of current estuary management, and monitor the long-term health of the estuary.

2.2.3 EPA Great Lakes National Program Office (GLNPO)

The Great Lakes National Program (GLNP) is part of the EPA. Annual monitoring of the Great Lakes by the GLNP began in 1983 for Lakes Michigan, Huron, and Erie; in 1986 in Lake Ontario; and in 1992 for Lake Superior (EPA, 2000b). GLNPO's Great Lakes Monitoring Program consists of several different elements, including the following:

- Green Bay Mass Balance Study,
- Lake Michigan Mass Balance Project,
- Benthic Invertebrate Monitoring Program,
- Limnology Program, and
- GLNP Indicators Monitoring Program.

Each of these program elements is briefly described below.

The Green Bay Mass Balance (GBMB) Study was conducted in 1989 through 1990 to pilot the technique of mass balance analysis in understanding the sources and effects of toxic pollutants in the Great Lakes food chain. The study was headed by EPA's GLNPO and the Wisconsin Department of Natural Resources. The study focused on four representative chemicals or chemical classes: PCBs, dieldrin, cadmium, and lead (EPA, 2000b).

The Lake Michigan Mass Balance Project began in 1994 and was concluded in 1999. In addition to baseline environmental conditions (air and water temperature, transmissivity, etc.), samples of air, water, sediment and fish tissue have been analyzed for four particular biochemical chemicals of concern: mercury, PCBs, atrazine, and trans-nonachlor. The Lake Michigan Mass Balance study is helping scientists understand where these chemicals are entering the Lake and what happens to them as they move through the ecosystem.

The GLNP has recognized the potential importance of benthic indicator/integrator organisms in the evaluation and management of the Great Lakes, and in 1997 initiated a Benthic Invertebrate Biomonitoring Program to complement its current surveillance sampling. The data is used in conjunction with other physical, chemical, and biological data generated by GLNPO's surveillance program to provide an extensive picture of the condition of the lakes and how benthic invertebrates respond to it.

The GLNP's annual Limnology Program for the Great Lakes began in 1983. The limnology program provides information on key environmental factors that influence the food chain and fish of the Great Lakes. The sampling strategy is to collect water and biota samples at specific water depths from a limited number of locations in each lake twice every year.

The GLNP's Indicators Monitoring Program monitors plants and organisms that are particularly suitable for use as indicators of environmental conditions. The GLNP monitors diatom communities, zooplankton populations, benthic invertebrates, and exotic species in the Indicators Monitoring Program.

All of the GLNPO programs recognize the significance of environmental contamination, and all of them include the collection and chemical analyses of sediments. This indicates the usefulness of sediments as a sentinel of chemical contamination in the environment even when the monitoring objective is not focused on the effectiveness of sediment remediation. Table 2-1 shows some of the similarities among these five national and regional programs in terms of measuring environmental quality.

2.2.4 Disposal Area Monitoring System (DAMOS)

The New England district of the U.S. Army Corps of Engineers (USACE) created the DAMOS program in 1977. The DAMOS program was established to ensure that the disposal of dredged material from numerous industrialized harbors in New England placed in offshore disposal sites had no adverse effect on the environment. After placement of contaminated material, these sites were subsequently capped with clean material. These offshore, open-water disposal sites are located between Long Island Sound and Maine, and are under the jurisdiction of the New England Corps district.

The DAMOS monitoring program was implemented to: 1) ensure the physical integrity and stability of disposal mounds, 2) measure the impacts to bottom organisms around and returning to the disposal mounds, and 3) measure the effectiveness of capping in isolating disposed contaminated sediments (USACE, 1992). Monitoring under the DAMOS program follows a tiered approach, under which techniques in the higher tiers are used only when monitoring results of lower tiers indicate the need for further monitoring.

2.3 State Monitoring Programs—Wisconsin and Michigan

Before finalizing the long-term monitoring plan for the Lower Fox River and Green Bay remediation project, it was important to consider other ongoing state monitoring programs intended to evaluate many of the same valued resources and aquatic receptors under consideration for the Lower Fox River/Green Bay project. Sampling protocols, monitoring methods, species selection, and resource locations have already been determined for many of these programs where extensive databases have already been established. The goal of this review was to consider other programs already in place and how to efficiently adapt the Lower Fox River/Green Bay monitoring plan to complement these pre-existing programs. These programs may have larger goals to consider beyond the scope and spatial extent of the project area, but were helpful for developing the Lower Fox River/Green Bay monitoring plan.

2.3.1 Wisconsin State Fish Monitoring Program

The Wisconsin Department of Natural Resources conducts fish tissue monitoring as part of Wisconsin's Fish Contaminant Monitoring Program. Fish tissue sampling is conducted every 3 to 5 years and collection efforts are focused on the tributaries to Green Bay including the Lower Fox River. The program has two goals: 1) updating the state fish consumption advisories for consumable fish and 2) determining temporal trends in fish indicator species. Spatial differences and temporal trends in consumption are examined by collecting several species of fish from three different river reaches of the Lower Fox River: 1) Little Lake Butte des Morts, 2) Appleton to the De Pere dam, and 3) below the De Pere dam to the mouth. Multiple samples are collected from at least three size classes of fish from each species (Table 2-3). Sampling events are conducted in the spring during spawning seasons.

Fish species used for evaluation of the consumption advisories include: walleye, carp, white bass, yellow perch, catfish, northern pike and two pan fish species (crappie and bluegill). Yellow perch are also collected from the south end of Green Bay. Although Lake perch is an exotic species, it may be added to the game fish collection list since it is desirable by anglers (Amhrein, 2000). These species and sizes represent WDNR's "guideline" of catches, but actual sampling catches may vary from year to year depending upon site conditions. The top fish species caught in the Lower Fox River are generally walleye, white perch, yellow perch, and smallmouth bass. Discrete fish samples are analyzed as skin-on-fillet samples (skin-off-fillet for catfish) and analyzed for total PCBs, percent lipids, DDT for carp, and mercury for walleye. PCB congeners are not typically analyzed as part of this program. Fish length, weight, sex, and presence of external and internal fish tumors are also recorded (Amhrein, 2000).

The second goal of the monitoring program is to observe trends in contaminant concentrations for assessing the status of environmental health. Gizzard shad tissues are used to observe environmental trends. Although gizzard shad are not a desirable fish catch by anglers, they serve as a good indicators of environmental health. Samples are collected in the same manner as the fish consumption advisory sampling events, with the exception that whole body fish tissue samples are analyzed (Amhrein, 2000).

2.3.2 Wisconsin State Bird Monitoring Programs

The Wisconsin Department of Natural Resources conducts waterfowl, double-crested cormorant, and bald eagle monitoring as discussed below.

Waterfowl

The WDNR conducted a game bird sampling event in the mid-1980s to assess PCB and pesticide concentrations in bird tissue ingested by hunters. This sampling event led to the listing of mallard ducks on the waterfowl consumption advisory in 1987. The sampling event was conducted around the state at several locations with multiple samples per location (approximate sample size N = 8). Although a formal monitoring program is not currently in-place and no additional waterfowl sampling has been conducted by WDNR since the late 1980s (additional sampling data have been collected by USFWS in the 1990s), WDNR intends to conduct additional waterfowl tissue sampling events to update the advisory (Peterson, 2000).

Double-crested Cormorants

The WDNR and the U.S. Fish and Wildlife Service (USFWS) periodically conduct bioaccumulation and productivity monitoring studies on resident double-crested cormorant species. Following a ban on the use of DDT in North America in the 1970s, egg tissue residues have decreased by more than 80 percent and the Green Bay population has increased by a factor of 45 in the past 20 years (Stratus, 1999). A summary of the types of monitoring conducted on resident populations in the past 20 years include:

- Whole body tissue (male and female) for total PCB and DDE analysis;
- Incidence of bill and head deformities among nestlings;
- Eggshell thickness;
- Biomarker activity—EROD activity in embryo livers;
- Edema of the head and neck of nestlings, and hemorrhaging;
- Annual productivity and nesting sites;
  - Number of nests
  - Number of hatches per active nest
  - Number of dead embryos
- Foraging areas; and
- Comparison to inland reference sites.

Details regarding sample collection efforts were not specified; however, it appears that several colonies were sampled per year with up to 40 nests and over 100 egg samples per colony for an annual sampling event. Egg samples were analyzed for total PCBs, PCB congeners, and DDE. Based on numerous correlation analyses, the best monitoring indicators of bird health were whole body and egg tissue chemical analysis, reproductive hatching success, and embryonic deformations. The main breeding colonies reside on Cat, Jack, Hat, and Snake Islands in Green Bay, and on Spider Island on the east side of Door peninsula. Breeding times occur between April and September/October before the colonies migrate south.

Recent studies by the USGS and USFWS identified DDE, and not other contaminants of concern, as the significant risk factor effecting reproductive success to double-crested cormorants (Custer *et al.*, 1999). Egg hatching success was positively correlated with shell thickness and negatively correlated with DDE concentration. Results did not support the hypothesized relationship between PCB concentrations in eggs and reproductive success in double-crested cormorants (Custer *et al.*, 1999). In summary, double-crested cormorant populations are recovering in Green Bay, are no longer a threatened species in Wisconsin, and are not good indicators of PCB risk to ecological receptors. However, they are vulnerable to PCB uptake by feeding almost exclusively on forage fish (alewife and smelt) with high lipid contents (Stratus, 1999) and have notably higher PCB concentrations in colonies residing on Cat Island (close to the Lower Fox River) than other colonies. They could serve as resident indicators of changes in PCB exposure and uptake over time.

Bald Eagles

The WDNR has conducted annual monitoring of bald eagles in the Lower Fox River/Green Bay region since 1974 (Dykstra and Miller, 1996). The USFWS also periodically conducts bald eagle monitoring for productivity, and PCB and DDE bioaccumulation in eggs and plasma. In 1997, the State of Wisconsin "threatened species" status was removed since bald eagle populations have significantly increased in the last 10 years; however, the bald eagle is still listed on the USFWS threatened species list. A summary of the types of monitoring conducted on resident bald eagle populations in the past 20 years include:

- Egg tissue for total PCB and DDE analysis (1986 to 1997);
- Blood plasma for total PCB and DDE analysis (1987 to 1995);
- Annual productivity and nesting sites;
  - Number of occupied and unoccupied nests
  - Number of large young produced per active nest
- Prey species and prey remains;
- Food availability and foraging areas; and
- Comparison to inland nesting sites.

In Green Bay, 12 nests were sampled with two to three eggs collected per nest. In the Lower Fox River, only one nest was sampled with one egg analyzed. Chemical analysis focused on PCBs and DDE because: 1) they are the only contaminants that have been found in the Great Lakes bald eagle tissues in high enough concentrations to result in adverse effects, 2) they are the most closely correlated with bald eagle reproductive success, and 3) they are known to result in the types of adverse effects observed in the area assessment of bald eagles

(Stratus, 1999). Reproductive rates have slowly increased since 1987, but rates are still 60 percent lower than inland nesting samples. PCB concentrations in eggs and blood samples from Green Bay were 10 times higher than inland samples (Dykstra and Miller, 1996). The annual productivity rate required to maintain a healthy bald eagle population is a minimum of 1.0 young per active nest.

2.3.3 Michigan State Fish Monitoring for Consumption Advisories

The state of Michigan conducts annual fish tissue monitoring as part of Michigan's Fish Contaminant Monitoring Program. In 1986, a comprehensive program was initiated by the Michigan Department of Environmental Quality-Surface Water Quality Division (MDEQ-SWQD) to assess the degree of chemical contamination in fish from surface waters of the state, and over 12,000 fish tissue samples have been analyzed since 1980. The program has four program goals: 1) to develop and maintain the Michigan Fish Advisory, 2) to regulate sales of commercial catch, 3) to identify spatial differences and temporal trends in the quality of Michigan's surface waters, and 4) to determine whether existing regulatory and remedial programs are effectively reducing chemical contamination in the aquatic environment (MDEQ, 1999). Temporal trends and spatial differences are examined by collecting whole-fish and caged-fish samples in addition to the edible portion samples. The presence of even extremely low concentrations of some bioaccumulative pollutants in surface water can result in concentrations in fish tissue that pose a human and wildlife health risk. Verification of the achievement of, or progress towards, the program goals is evaluated primarily through the collection and analysis of fish tissues.

Components of the fish monitoring program include:

- Edible fish monitoring;
- Whole fish trend monitoring (initiated in 1990); and
- Caged fish chemical bioconcentration studies.

Edible fish monitoring samples are collected every year from inland lakes and rivers, tributary rivers, and Lake Michigan (Day, 2000). In 1998, 1,059 fish were collected from 58 locations and included 21 species of fish; however, none of these 1998 stations were located in the project area. The sampling stations are not on a fixed schedule; samples are collected opportunistically based on fish catches. Collection and analysis focus on key species of concern and fish samples are generally processed as headless, gutless, and skin-off fillets for most fish, with the exception of game fish which are mostly skin-on-fillet. Samples are discrete(no compositing) since MDEQ rarely collects composite samples except for coho and chinook salmon species (Day, 2000).

Whole fish trend monitoring samples are collected every 2 to 5 years from 26 trend locations to assess the spatial and temporal trends in contaminant concentrations. However, only four rounds of data sets have been collected to date, and significant trends have not been detected in most of these data sets, possibly due to sample variability. Only two stations are located with the project area; one station is located near Little Bay de Noc in Green Bay and other is located in the Menominee River tributary to Green Bay.

Caged fish bioconcentration studies are used as a tool to identify sources of bioaccumulative contaminants and identify spatial trends in contaminant concentrations. MDEQ generally places approximately 10 to 30 cages per year (Day, 2000). The caged-fish studies consist of a 28-day test using channel fish (4 to 6 inches long) and are conducted primarily in river watersheds (River Raisin, Saginaw River) and none are located in the project area.

In addition to the Michigan Fish Contaminant Monitoring Program, several agencies in the Great Lakes Basin are monitoring fish contaminant trends. The EPA collects and analyzes whole lake trout or walleye from the open waters of each of the Great Lakes. The Great Lake states work cooperatively with the EPA to collect and analyze coho and chinook salmon from select Great Lake tributaries during the fall spawning migration. The coho and chinook salmon are analyzed as composites of skin-on fillets.

2.3.4 Existing Data for the Lower Fox River and Green Bay

The sediment, water, and tissue data sets used for the Lower Fox River and Green Bay RI/FS project were compiled from over 16 different site characterization studies (Table 2-4). The compiled data set spans over 20 years for certain parameters, and was used to calculate sediment quality thresholds as part of the Baseline Ecological and Human Health Risk Assessment (ThermoRetec, 2000b). The data set includes primarily surface sediment, sediment core, and water quality data.

The purpose of presenting this compilation of existing data for the Lower Fox River and Green Bay is to summarize the types of monitoring parameters already collected in the project area. This data constitutes a remarkable set of baseline data that could be used to detect and determine long-term trends at the site well after post-project remediation. This compilation is not intended to replace a well-developed long-term monitoring plan including a revised set of baseline data that would be directly comparable to long-term data (similar sites, sizes, depths, and types of data), but serves to augment and detect temporal trends.

As summarized in Table 2-5, the types of monitoring elements commonly collected in the Lower Fox River and Green Bay include: surface and subsurface sediment sampling, fish tissue sampling, and mammal sampling with lesser amounts of air, water, and caged fish sampling data. Benthic community abundance and fish tissue deformities/histopathology were not commonly collected.

As described in the Lower Fox River RI/FS Data Management Summary Report (EcoChem, 2000), several of the studies used many different analytical laboratories with different detection limits, different analyte lists, and a wide range of reported percent recoveries and data validation procedures. Thus, it was determined that, in general, the data from the Green Bay Mass Balance Study, along with many other studies listed in this document, should be used as supporting data only. When planning the long-term monitoring plan for the Lower Fox River and Green Bay, consistency between years, laboratories, analytical methods, and detection limits will assist with reliable interpretations of temporal and spatial trends.

Table 2-1 Regional and National Monitoring Programs

Monitoring Program	Environmental Quality Measurement Elements									
	Physical	Chemical		Biological						
	Bathymetry and Sediment	Surface Water Quality	Surface Sediment Quality	Benthic Abundance	Fish Community	Sediment Invertebrate Toxicity	Water Toxicity	Fish and Shellfish Tissue	Invertebrate Tissue	Histological Studies
National Programs										
EMAP	◆		◆	◆	◆			◆	◆	
NOAA NS&T			◆					◆	◆	◆
Regional Programs										
DAMOS	◆		◆	◆		◆		◆	◆	
GLNP		◆	◆	◆	◆			◆	◆	
PSAMP	◆		◆	◆		◆				
SF-Bay Estuary Program	◆	◆	◆	◆		◆	◆	◆	◆	

Table 2-2 State Monitoring Programs—Wisconsin and Michigan

State Monitoring Program	Physical	Chemical			Biological			
	Other	Sediment	Surface Water	Sediment Traps	Benthic Abundance	Toxicity	Concentration Tissue	Histological Studies
Wisconsin State Fish Consumption Monitoring Program							◆	
Wisconsin State Bird Monitoring Program							◆	
Waterfowl							◆	
Double-crested Cormorant							◆	◆
Bald Eagle							◆	
Wisconsin Sensitive Areas Index Monitoring	◆							
Michigan State Fish Consumption Monitor Program							◆	
USACE Navigational Depth Monitoring	◆							

Table 2-3 1998 Wisconsin Fish Contaminant Sample Collection Schedule

Sampling Location	Species	Sampling Guidelines (source: J. Amhrein)			
		Size Class (in inches)	No. of Samples	Sample Form	Parameters
Little Lake Butte des Morts	Walleye	12-15	1	fillet	PCBs
		15-18	4	fillet	PCBs
		18-22	3	fillet	PCBs
		22-24	1	fillet	PCBs/Hg
	Northern Pike	15-18	3	fillet	PCBs
		18-22	3	fillet	PCBs
		22-26	2	fillet	PCBs
	Carp	many	5	fillet	PCBs
	Yellow Perch	many	5	fillet	PCBs
	Smallmouth Bass	10-12	1	fillet	PCBs
		12-15	3	fillet	PCBs
		15-17	2	fillet	PCBs
	White Bass	9-11	2	fillet	PCBs
		11-14	3	fillet	PCBs
		14+	1	fillet	PCBs
	Bluegill	many	5	fillet	PCBs
	Crappie	many	5	fillet	PCBs
	Gizzard Shad	2-25 fish composites	50	whole	PCBs
	Shiner spp.	2-25 fish composites	50	whole	PCBs
Lower Fox River below the De Pere Dam	Walleye	10-12	2	fillet	PCBs
		12-15	3	fillet	PCBs
		15-18	3	fillet	PCBs
		18-22	3	fillet	PCBs
		22-24	2	fillet	PCBs/Hg
	Northern Pike	15-18	2	fillet	PCBs
		18-22	2	fillet	PCBs
		22-26	2	fillet	PCBs
	Smallmouth Bass	10-12	2	fillet	PCBs
		12-15	2	fillet	PCBs
		15-18	2	fillet	PCBs
	White Bass	many	5	fillet	PCBs
	Bluegill	many	5	fillet	PCBs
	Crappie	many	5	fillet	PCBs
	Yellow Perch	many	5	fillet	PCBs
	Carp	many	5	fillet	PCBs
	Gizzard Shad	2-25 fish composites	50	whole	PCBs
	Shiner spp.	2-25 fish composites	50	whole	PCBs
Lower Fox River above the De Pere Dam	Walleye	10-12	2	fillet	PCBs
		12-15	3	fillet	PCBs
		15-18	3	fillet	PCBs
		18-22	3	fillet	PCBs
		22-24	2	fillet	PCBs/Hg
	Northern Pike	15-18	2	fillet	PCBs
		18-22	2	fillet	PCBs
		22-26	2	fillet	PCBs
	Smallmouth Bass	10-12	2	fillet	PCBs
		12-15	2	fillet	PCBs
		15-18	2	fillet	PCBs
	White Bass	many	5	fillet	PCBs
	Bluegill	many	5	fillet	PCBs
	Crappie	many	5	fillet	PCBs
	Yellow Perch	many	5	fillet	PCBs
	Carp	many	5	fillet	PCBs
	Gizzard Shad	2-25 fish composites	50	whole	PCBs
	Shiner spp.	2-25 fish composites	50	whole	PCBs
Green Bay	Gizzard Shad	1 lb young-of-the-year	3	whole	PCBs, Chlor, Dieldrin, DDT
	Yellow Perch	2-5 fish composites	10	fillet	PCBs, Chlor, Dieldrin, DDT

Table 2-4 Compilation of Existing Data for the Lower Fox River and Green Bay RI/FS Project

Study	Years	Location	Monitoring Matrix	OK to Use
WDNR Fox River and Green Bay Mass Balance Studies	1989/1990	river-wide, bay-wide	Over 4,000 sediment and surface water samples	(1)
Deposit A Sampling Collection	1992–1994	Deposit A	Sediment and water samples (BBL, 1993; WWC, 1994)	Yes
Lake Michigan Mass Balance Study	1994–1995	bay-wide	7,000 sediment, water, tissue, and air samples	Yes
1994 GAS/SAIC Sediment Sampling	1994	De Pere to Green Bay	253 sediment samples	Yes
FRG 1996 Sediment and Tissue Sampling	1996, 1998	river-wide, bay-wide	Over 1,000 sediment, water and fish tissue samples	Yes
WDNR Fish Tissue Collection	1996	river-wide	20 fish tissue samples	Yes
WDNR Bird and Mammal Tissue Collection	1984–1996	river-wide	Bird and mink tissue	(1)
USFWS NRDA Fish Tissue Collection	1996	De Pere and Green Bay	376 fish tissue samples	Yes
USFWS NRDA Bird Tissue Collection	1993–1997	De Pere and Green Bay	193 cormorant tissue, 200 tree swallow tissue, 31 eagle samples	(1)
Fish Consumption Advisory Data	1971–1996	river-wide, bay-wide	Over 2,000 fish tissue samples	(1)
Lake Michigan Fish Consumption Advisory Data	1983–1999	Green Bay zones 3 & 4	434 fish tissue samples	(1)
Lake Michigan Tributary Study	1990?	river-wide	88 surface water samples	Yes
USGS National Water Quality Program	1992–1997	only 10% from LFR	441 samples of sediment, water, and tissue	(1)
RETEC RI/FS Data Collection	1998	river-wide	252 sediment and fish tissue samples	Yes
Deposit N Demonstration Project	1997–1999	Deposit N	Sediment, water, 25 caged fish	Yes
SMU 56/57 Demonstration Project	1998–1999	SMU 56/57	Sediment, water, caged fish	Yes

Source: Lower Fox River and Green Bay RI/FS Project Database. Database Management Report (EcoChem, 2000).

Table 2-5 Distribution of Existing Sediment, Water, and Tissue Data in the Lower Fox River and Green Bay over Time

Year	Number of Samples Analyzed for Total PCBs				QA Status		
	Sediment	Tissue (caged)	Tissue (resident)	Water	Validated	Supporting	Blank
1971			14			14	
1975			26			26	
1976			53			53	
1977			62			62	
1978			70			70	
1979			67			67	
1980			69			69	
1981			73			73	
1982			68			68	
1983			51			51	
1984			92			92	
1985			195			195	
1986			97			97	
1987	203		118			321	
1988	161		70			231	
1989	1,354		604	615		2,573	
1990	104		54	197		355	
1991			40			40	
1992	35		233	8	27	249	
1993	70		106	5	67	114	
1994	296		122	54	299	152	21
1995	484		87	40	484	109	18
1996	8		416		255	169	
1997	288		119		370	37	
1998	528	20	375	310	1,233		
1999	43	6	9	20	70	8	
TOTAL	**3,574**	**26**	**3,290**	**1,249**	**2,805**	**5,295**	**39**

8,139 Records

Summary of Data Query		
TOTAL RECORDS	453,394	
Total PCBs (lipid normalized)	80	(not used)
Total Aroclor	215	(not used)
"TOTAL PCBs" Query	9,710	used
YEAR = NONE	31	discarded
	9,679	
Locations outside of project area	1,540	discarded
Total # of samples in query	8,139	

Notes:

1 Resident caged tissue includes fathead minnows only.

2 Refer to the resident tissue worksheet tables for a breakdown of tissue types for the Lower Fox River and Green Bay.

3 The data query was for all samples collected over time for "total PCBs" analysis, and includes the sum of PCB congeners analyses.

4 The data query was limited to the four reaches of Lower Fox River and the four zones of Green Bay.

5 Samples without a year or location designation were eliminated from the data query.

6 The database does not have any air samples for total PCBs analysis.

7 Approximately 100 of the water samples collected in 1998 were from the Deposit N and SMU 56/57 demonstration project studies (during dredging).

Table 2-6 Distribution of Resident Tissue Samples over Time in the Lower Fox River

Year[3]	Fish												Birds					Mammals	Other
	Benthic Fish			Game Fish			Pelagic Fish			Trout			Raptors	Swallow	Upland Game Bird	Waterfowl		Fur Bearer	Insect/ Invertebrate
	No. of Samples	No. of Species	No. of Whole Fish Samples	No. of Samples	No. of Species	No. of Whole Fish Samples	No. of Samples	No. of Species	No. of Whole Fish Samples	No. of Samples	No. of Species	No. of Whole Fish Samples	No. of Samples	No. of Samples	No. of Samples	No. of Samples	No. of Species	No. of Samples	No. of Samples
1971	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	6	2	0	11	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	24	3	6	12	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	24	3	9	14	3	8	0	0	0	4	1	0	0	0	0	0	0	0	0
1979	12	3	8	16	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0
1980	36	4	11	25	5	9	1	1	1	0	0	0	0	0	0	0	0	0	0
1981	23	3	14	18	3	8	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	28	3	5	24	6	3	2	1	0	0	0	0	0	0	0	0	0	0	0
1983	8	3	2	10	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	8	2	2	14	7	0	0	0	0	0	0	0	0	0	1	3	1	1	1
1985	15	3	0	35	4	0	0	0	0	0	0	0	1	0	0	12	1	0	0
1986	16	4	2	18	3	2	1	1	1	0	0	0	0	0	0	28	1	0	0
1987	34	5	1	43	7	1	1	1	1	0	0	0	0	0	0	22	1	0	0
1988	7	2	0	6	2	0	0	0	0	0	0	0	0	0	0	6	1	0	0
1989	42	3	24	38	1	26	20	2	20	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
1991	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	20	2	8	111	9	9	4	1	4	0	0	0	0	0	0	0	0	0	0
1993	15	1	15	0	0	0	0	0	0	0	0	0	0	51	0	0	0	0	1
1994	10	2	5	13	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1996	109	6	84	185	7	34	13	3	13	0	0	0	0	0	0	0	0	0	0
1997	3	1	3	17	1	0	0	0	0	0	0	0	0	0	0	22	2	0	0
1998	93	4	48	198	7	59	17	3	17	0	0	0	0	0	0	0	0	0	10
1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes:

[1] No piscivorous birds were collected in the Lower Fox River.
[2] No cormorants were collected in the Lower Fox River.
[3] Samples included in the Lower Fox River and Green Bay RI/FS database.

Table 2-7 Distribution of Resident Tissue Samples over Time in Green Bay

Year[4]	Fish												Birds									Mammals		Other
	Benthic Fish			Game Fish			Pelagic Fish			Trout			Cormorant		Piscivorous Birds		Raptors	Swallow		Waterfowl		Deer	Fur Bearer	
	No. of Samples	No. of Species	No. of Whole Fish Samples	No. of Samples	No. of Species	No. of Whole Fish Samples	No. of Samples	No. of Species	No. of Whole Fish Samples	No. of Samples	No. of Species	No. of Whole Fish Samples	No. of Samples	No. of Species	No. of Samples	No. of Species	No. of Samples	No. of Samples	No. of Species	No. of Samples	No. of Species	No. of Samples	No. of Samples	No. of Samples
1971	0	0	0	0	0	0	0	0	0	14	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1975	7	1	0	18	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	15	3	0	20	8	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	5	2	0	21	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	7	2	1	9	2	2	7	3	1	5	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1979	8	4	8	17	4	9	9	3	9	5	3	5	0	0	0	0	0	0	0	0	0	0	0	0
1980	3	1	0	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	15	1	15	13	2	0	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	5	1	0	4	1	0	0	0	0	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	12	3	2	13	4	0	4	1	2	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	8	3	0	23	6	0	9	4	4	20	4	0	0	0	0	0	0	0	0	4	2	0	0	0
1985	0	0	0	3	2	0	4	3	3	125	5	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	5	1	0	9	3	0	2	1	2	3	2	0	0	0	1	1	0	0	0	13	1	0	0	1
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	16	3	1	0	0
1988	20	2	0	11	2	0	10	1	0	0	0	0	0	0	0	0	0	0	0	10	2	0	0	0
1989	166	1	77	101	2	66	169	3	169	68	3	39	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	22	3	0	9	2	9	22	2	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	5	1	0	16	2	0	18	3	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	10	1	10	35	3	10	7	2	7	46	5	3	0	0	0	0	0	0	0	0	0	0	0	0
1993	6	2	4	0	0	0	2	1	2	16	2	0	0	0	0	0	0	15	1	0	0	0	0	0
1994	0	0	0	19	2	0	4	1	4	16	3	0	60	1	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	1	1	0	4	1	4	0	0	0	80	1	0	0	0	0	0	0	0	0	0	1
1996	0	0	0	60	3	24	0	0	0	29	4	19	0	0	15	2	0	0	0	5	1	0	0	0
1997	0	0	0	71	2	15	0	0	0	1	1	0	0	0	5	1	0	0	0	0	0	0	0	0
1998	12	2	12	32	4	22	8	2	8	0	0	0	0	0	0	0	0	0	0	2	1	0	0	3
1999	0	0	0	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

Notes:

[1] No reptiles were collected in Green Bay.
[2] No upland game birds were collected in Green Bay.
[3] Date query included all samply body types. The number of whole samples included whole fish and whole fish composites for fish, and whole body for birds.
[4] Samples included in the Lower Fox River and Green Bay RI/FS database.

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3 Guidance Documents for the Development of Monitoring Programs

The primary goal of monitoring is to produce information that is useful in making management decisions. The creation of useful information depends on clear monitoring objectives and appropriate technical design. The goals and objectives established for a monitoring plan should be scientifically, technologically, logistically, and financially achievable and comparable to management parameters. To determine appropriate technical design for monitoring programs and to ensure adequate data collection, analysis, and interpretation for management-based decisions, a review of relevant regulatory and agency guidance documents was conducted.

Guidance documents reviewed fell into two categories: 1) research and panel-type discussions that identified general but important elements needed for a successful evaluation of remediation projects, and 2) detailed regional guidance documents that specifically recommend the quantity, types, and frequency of sampling parameters. The guidance documents reviewed included:

- EPA Guidance for Development of Fish Consumption Advisories;
- EPA Guidance for Conducting RI/FS Studies Under CERCLA;
- Great Lakes Protocol for Sport Fish Consumption Advisories;
- EPA ARCS Program Assessment Guidance Document; and
- OSWER Use of Monitored Natural Recovery at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites.

Since a comprehensive guidance document for designing and implementing a long-term monitoring program for contaminated sediments does not exist, these relevant guidance documents could be applied to the Lower Fox River and Green Bay remediation project.

3.1 EPA Guidance for Development of Fish Consumption Advisories

The EPA document titled *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* (EPA, 1995), provides technical guidance to State and local agencies on methods for sampling and analyzing contaminants in fish and shellfish tissue that will promote consistency between data sets used to determine the need for fish consumption advisories. State agencies routinely conduct chemical contaminant analysis of fish and shellfish tissues as part of their comprehensive water quality monitoring programs. If states conclude that consumption of chemically contaminated fish and shellfish poses an unacceptable risk to human health via consumption, they may issue local fish consumption advisories or bans for specific fish species and water bodies. Although the document does not constitute regulatory requirements for the states, it was formulated to improve data consistency after inconsistencies were identified between 150 publications on seafood contamination. The primary shortcomings included: 1) analysis of nonedible portions of fish, 2) different reporting methods, and 3) lack of crucial information regarding percent lipid, fish size and weight, and contaminant concentrations.

A summary of the recommendations provided in the guidance document are listed below, many of which maybe helpful during the formulation of a long-term monitoring plan for the Lower Fox River and Green Bay RI/FS. The recommendations include:

- Target fish species should include at least one bottom feeder and one predator.

- Target species for Great Lakes waters should include a combination of species from the selected list of: white bass, smallmouth bass, walleye, common carp, white sucker, channel catfish, muskellunge, chinook salmon, lake trout, brown trout, or rainbow trout.

- For the bottom feeder target species, the recommended selection, whenever practical, is common carp, channel catfish, and white sucker, respectively.

- Samples should be collected from harvest areas that have a high probability of contamination.

- Samples should be collected during the legal harvest season when target species are most available to consumers.

- In fresh waters, as a general rule, the most desirable sampling period is from late summer to early fall (August through October). The lipid content of many species (which represent an important reservoir for organic pollutants) is generally highest at this time.

- Collect composite fillet samples for each target fish species (200 g). Individual organisms used in composite samples should be of similar size and collected at the same time. Use skin-on fillets (with belly flap) for scaled species and skin-off fillets for scaleless species. Use edible portions of shellfish. States may use individual fish samples or whole fish and other sample types if necessary to improve exposure estimates of local seafood-consuming populations.

- Samples should include three size classes of the target species. For cost effectiveness, if only one size class of a target species is collected, then the collection effort should focus on larger individuals commonly harvested by the local population.

- Replicate composite samples are recommended.

- For each target species, compare target analyte arithmetic mean concentrations or replicate composite samples with screening values.

- Sampling sites should be located near sites selected for water and sediment sampling for the possibility of correlating contaminant concentrations in different media.

- Each sample location should include: sample site name, water body name, type of water body, coordinates, scientific and common name of species, sampling date and time, sampling gear type used, sampling depth, number of individual organisms used in composite, predominant characteristics of specimens (sex, life stage, total length, body size), description of sample type (fillet, whole fish), total weight, percent lipid, analytical methods, and concentrations (for wet weight in grams).

If resources allow, states may wish to consider documenting external gross morphological conditions in fish from contaminated waters. Severely polluted aquatic habitats have been shown to produce a higher frequency of gross pathological disorders than similar less polluted habitats. Morphological conditions acceptable for use in monitoring programs include: fin erosion, skin ulcers, skeletal anomalies, and neoplasms (i.e., tumors).

3.2 EPA Guidance for Conducting RI/FS Studies Under CERCLA

In the EPA document titled *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988), monitoring for long-term effectiveness and permanence is discussed when evaluating alternatives and costing (EPA, 1998). The document does not propose regulations, but rather describes how existing statutory and regulatory authorities will be used by EPA to deal with contaminated sediment problems (Zar, 1995). The primary focus of the discussion is to evaluate the risk remaining at the site after response objectives have been met. Although specific elements required for a long-term monitoring plan were not stated, the guidance document included specific components that should be addressed for each alternative:

1. Magnitude of residual risk; and
2. Adequacy and reliability of controls.

The magnitude of residual risk should be analyzed by identifying the remaining sources of risks and how much of the risk is due to untreated residual contamination verses continued source inputs. The adequacy and reliability of controls should be analyzed by identifying the difficulties and uncertainties associated with long-term monitoring and maintenance, the degree of confidence that controls can adequately handle potential problems, and what operation and maintenance functions must be performed.

A summary of the recommendations provided in the guidance document that may be helpful during the formulation of a long-term monitoring plan for the Lower Fox River and Green Bay RI/FS study include:

- Calculate the magnitude of residual risk;

- Carefully consider the integrity of institutional controls and isolation mechanisms, and the amount of sampling that can be applied to each remedy over time without compromising function; and

- Carefully consider the need for source control monitoring.

3.3 Great Lakes Protocol for Fish Consumption Advisories

A Great Lakes Advisory Task Force was convened in the early 1990s to develop uniform protocols for developing Great Lakes fish consumption advisories. The resulting document was titled *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.*, 1993) after realizing the need to develop a uniform procedure for sampling, analyzing, and listing of fish species on a state consumption advisory list. The states involved in the drafting committee included state regulators from Wisconsin, Michigan, and Minnesota. Details regarding the fish collection procedures, analyses, and recommended species were not reviewed. However, the 1998 Wisconsin Fish Contaminant Sample Collection Schedule list described in Section 2 represents ongoing fish sampling activities that are in general accordance with the recommendations of the Great Lakes Advisory Task Force.

The task force assumed that the health protection value developed for PCB concentrations in fish would in most instances account for the majority of potential risk from a mixture of chemicals present in fish. For areas where other contaminants are present but not predominant, the health protection value for PCBs would be protective even considering possible additive effects (Anderson *et al.*, 1993). The State of Wisconsin risk-based advisory for the Great Lakes and inland waters sets a "health protection" value for PCBs at 5.0×10^{-5} mg PCB/kg-bw-day. Fish under 0.05 ppm PCB have no consumption restrictions. The FDA's interstate commerce level for the protection of human health is set at 2.0 ppm PCB.

Based on our review of this document, recommendations for development of the Lower Fox River and Green Bay monitoring plan include:

- Use recommended fish species listed in the 1998 Wisconsin fish collection schedule for the protection of human health, and

- Focus our analyses of fish tissue samples on PCBs and mercury for the protection of human health.

3.4 EPA ARCS Program Guidance Document

The EPA document titled *Assessment and Remediation of Contaminated Sediments (ARCS) Program - Assessment Guidance Document* (EPA, 1994) describes types of monitoring elements (sediment chemistry, sediment toxicity, and benthic community structure) commonly used in the Great Lakes regions. The document provides guidance on procedures for assessing the nature and extent of sediment contamination as applied to areas in the Great Lakes region. It was prepared under the Assessment and Remediation of Contaminated Sediments (ARCS) Program, administered by the EPA GLNPO. Although the document does not represent enforcement measures for long-term monitoring requirements, it does provide a foundation of acceptable methods for monitoring and assessing the status and trends of a contaminated sediment site. Monitoring methods used by the ARCS program to determine the nature and extent of sediment contamination in the Great Lakes Areas of Concern (AOC) basically expanded on the sediment quality triad approach and included:

- Sediment chemistry,
- Sediment toxicity,

- Benthic invertebrate community structure, and
- Fish tumors and abnormalities.

General recommendations summarized in the ARCS document that may be applicable to the Lower Fox River and Green Bay RI/FS monitoring program include:

- Use several complimentary methods to assess sediment impacts to biological organisms rather than relying on a single monitoring parameter.

- If conclusions differ between many monitoring parameters, then the differences indicate a need for caution when interpreting the data. Unusual site-specific circumstances may be confounding a clear interpretation of the data.

- If sediment toxicity tests are used, then a minimum of two or three toxicity tests should be used with at least three measured responses (i.e., survival, growth, or reproduction).

- Benthic community structure analysis should be considered in addition to toxicity tests to provide an important compliment to laboratory tests because changes in benthic communities are likely the result of long-term exposures not adequately simulated in the laboratory.

- Surveys of liver lesions in bottom-dwelling fishes have been shown to provide valuable evidence of damage to resident organisms potentially resulting from exposure to contaminated sediments.

Although these recommendations are useful, they focus mostly on the assessment of sediment quality and environmental impacts to the benthic community and not on the risk to human health and fish health. Monitoring efforts will focus on fish, bird, and invertebrate tissue sampling to assess the bioaccumulation of contaminants in biological receptors, as opposed to sediment toxicity tests. Tissue monitoring, along with reproductive viability of birds and mammals, are appropriate methods for verifying achievement of the project RAOs.

3.5 EPA Use of Monitored Natural Attenuation

The EPA's Office of Solid Waste and Emergency Response (OSWER) produced a document titled *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (EPA, 1999b) describing the appropriateness of using monitored natural attenuation for the remediation of contaminated soil and groundwater at sites regulated under all OSWER programs. Although this guidance document is not explicitly intended for remediation of contaminated sediments, it will serve as a point of reference for natural attenuation considerations on the Lower Fox River and Green Bay since no other guidance documents currently exist. The purpose of this directive is to clarify EPA's policy regarding the use of monitored natural attenuation (MNA) and to provide technical guidance to the public and the regulated community on how EPA intends to exercise its discretion in implementing its regulations; however it is not a regulation itself.

The term "monitored natural attenuation" refers to the reliance on natural attenuation processes to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active remediation methods. These processes work to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These *in-situ* processes include: biodegradation, dispersion, dilution, sorption, volatilization, radioactive decay, and chemical or biological stabilization, transformation, or destruction of contaminants.

EPA generally expects that MNA will only be appropriate for sites that have a low potential for contaminant migration and that the use of MNA must be protective of human health and the environment. Performance monitoring for MNA is of even greater importance than other remedies due to the potentially longer remediation time frames, potential for ongoing contaminant migrations, and other uncertainties associated with using MNA. The frequency of monitoring should be adequate to detect, in a timely manner, potential changes in site conditions. At a minimum, the monitoring program should be sufficient to enable determination of the attenuation rate and how that rate is changing with time. The monitoring plan should allow flexibility in the sampling frequency over the life of the remedy to allow for changing conditions. When establishing contingency and/or action plans based on unacceptable monitoring results, care is needed to ensure that sampling variability or seasonal fluctuations do not unnecessarily trigger a contingency. Performance monitoring should continue until remediation objectives have been achieved and verified.

For the Lower Fox River and Green Bay RI/FS project, the term "monitored natural attenuation" will be referred to as "monitored natural recovery" or "MNR." A summary of the recommendations provided in the guidance document that may be helpful during the formulation of a long-term monitoring plan for the Lower Fox River and Green Bay RI/FS study follows:

- Monitored natural recovery should be considered for areas where there is adequate source control.
- MNR alternative should be able to compare upgradient and downgradient sampling results.
- Sampling strategy should allow for flexibility and adaptive management over time.

4 Recommendations and Selection of a Monitoring Plan Strategy

The National Research Council (NRC) reviewed numerous reports and monitoring programs related to the management of contaminated sediments. Based on their review, they developed a conceptual model for the design and implementation of monitoring programs and defined the role of monitoring in marine environmental management (NRC, 1990). Several evaluation parameters were identified to ensure development of an adequately designed monitoring program. These management factors were used as a screening process to select appropriate monitoring elements (i.e., sediment chemistry, fish tissue chemistry, surface water chemistry, benthic abundance) for the Lower Fox River and Green Bay RI/FS project. Recommendations put forth by other regulatory groups regarding the management of contaminated sediments and recommendations based upon our review of monitoring programs (Section 2) are also discussed below.

4.1 National Research Council Contaminated Sediment Monitoring Recommendations

The Marine Board of the National Research Council has examined issues pertaining to the effectiveness of marine environmental monitoring in several studies over the period of a decade. Recognizing the growing need for national guidance on how to improve these monitoring programs, the National Research Council convened the Committee on a Systems Assessment of Marine Environmental Monitoring under the auspices of the Marine Board. The committee was asked to evaluate and make recommendations to improve the usefulness of monitoring information as a component of sound environmental management, and identify needed improvements in monitoring strategies and practices (NRC, 1990).

According to the committee, effective monitoring programs depend on formulating clear goals and objectives, developing an effective technical design, and translating data into information that is relevant and accessible to decision makers and the interested public (Figure 4-1). The recommended parameters of an effective monitoring program are discussed below.

4.1.1 Formulation of Clear Goals and Objectives

The ultimate goal of monitoring is to produce information that is useful in making management decisions. The creation of useful information depends on clear monitoring objectives. In order to develop clear monitoring objectives, the relevant questions and hypotheses to be addressed in the monitoring program must first be clearly identified. These specific questions to be answered by the monitoring program should be designed to meet specific information needs, and the questions should be testable. In addition, the goals and objectives established for a monitoring program should be achievable scientifically, technologically, logistically, and financially.

4.1.2 Effective Technical Design

An appropriate technical design is critical to the success of monitoring programs because it provides the means for ensuring that data collection, analysis, and interpretation address the needs and objectives of management. The goal of a monitoring plan design should be the detection of specific kinds and amounts of changes that are meaningful with respect to the resources at risk. Meaningful change is often confused with significant change. Significant change often refers to change in terms of statistical differences. However, whether changes in the environment are statistically significant has no bearing on the extent to which the changes may be either meaningful or important, for example, in terms of ecological or human consequences. An effective technical program design should also identify and quantify the sources of variability that may obscure or confound responses. The technical program design should also identify which variables to measure, in light of logistical constraints and limitations on scientific knowledge. An important consideration for any monitored variable is that it should be tied directly to the specific questions to be answered and the resources at risk. Changes in the status of the variable must unambiguously reflect changes in the resources at risk. Finally, the technical program design should be capable of being modified as a result of monitoring results.

4.1.3 Translation of Data into Useful and Accessible Information

An effective monitoring program also depends on the translation of data into information that is relevant and accessible to decision makers and the interested public. The monitoring program should provide mechanisms to ensure that knowledge is used to convert data collected into useful information. Effective data management is an essential tool for achieving this task. In addition, clear guidance is required on how data are to be used and what type of decisions are to be made.

Many monitoring programs have proved to be ineffective because they devote too little attention to the above topics. The committee reached the following overall conclusion related to designing and implementing monitoring programs:

> "Failure to commit adequate resources of time, funding, and expertise to up-front program design and to the synthesis, interpretation and reporting of information will result in failure of the entire program" (NRC, 1990).

Without the above commitments, effort and money will be spent collecting data and producing information that may prove to be useless. Figure 4-1 presents a flow chart for designing and implementing a monitoring plan which includes many of the elements discussed above. These recommendations are used later in Section 4 during the monitoring element selection process for application to the Lower Fox River and Green Bay long-term monitoring plan.

4.2 EPA Contaminated Sediment Remediation Strategy Recommendations

One of the key points repeatedly referenced in the EPA document titled *EPA's Contaminated Sediment Remediation Strategy* (EPA, 1998) is the development of standardized protocols for monitoring and interpretation of aquatic systems. EPA believes that they need to develop an agency-wide strategy for coordinating and managing contaminated sediments. The Office of Water intends to use standardized sediment toxicity and bioaccumulation test methods for monitoring of narrative water quality standards and dredged material disposal testing. When appropriate, EPA program offices intend to develop and use sediment quality criteria to assess contaminated sediment sites.

As stated in the document, EPA will consider a range of risk management alternatives including monitored natural recovery. EPA plans to develop criteria for determining when natural recovery is an appropriate remedial alternative using rates of recovery of benthic communities under different environmental conditions and stresses. Factors influencing the recovery rates (i.e., community types, physical factors, types of stresses) will be evaluated. One of the major uncertainties in assessing the effects of sediment-associated contaminants is the ecological significance of bioaccumulated compounds. The EPA Office of Research and Development will continue research on the bioavailability and trophic transfer of contaminants in sediment to shellfish and higher trophic level aquatic species resulting in both lethal and sublethal effects.

In summary, EPA plans to use standard sediment toxicity, bioaccumulation tests, and site-specific field-based methods (i.e., ELIZA immunoassay testing) to identify potential sites for remediation, to assist in determining cleanup goals for contaminated sites, and to monitor the effectiveness of remedial actions. Although EPA did not state specific requirements for long-term monitoring of contaminated sediment remediation projects in the *EPA's Contaminated Sediment Management Strategy* document (EPA, 1998), their research and attention over the upcoming years will likely focus on monitoring of sediment toxicity, benthic community abundance, and bioaccumulation testing as their management strategy is implemented. These elements identified by EPA as important management tools for contaminated sediment projects will help the Fox River and Green Bay remediation project formulate a long-term monitoring plan that will be consistent with EPA's long-term management strategies.

4.3 Monitoring Plan Recommendations Extracted from National, Regional and State Programs

Based on our review of regional, national, and state monitoring programs in Section 2, our recommendations for the Lower Fox River and Green Bay long-term monitoring plan are summarized below:

- Focus on surface water quality and fish tissue sampling to verify protection of human health.

- Conduct surface sediment sampling in areas selected for monitored natural recovery to assess potential recontamination of these areas.

- Long-term biological monitoring to assess environmental health should focus on either: 1) sediment toxicity and benthic community structure; or 2) fish, bird, shellfish, and invertebrate tissue sampling to assess declines in COC concentrations in tissue. This monitoring plan will focus on fish, bird, and invertebrate tissue sampling for PCBs, mercury, and DDE.

- Build upon the existing Fox River and Green Bay database which consists primarily of fish tissue data (20 years), sediment chemistry (15 years), and surface water chemistry (11 years).

- Focus fish tissue sampling on species presented in the project food web model and species of concern for evaluating fish consumption advisories.

- Focus bird tissue sampling on species of interest that have demonstrated sensitivity to contaminant uptake and reduced reproductive success when exposed to contaminants in the food chain (i.e, bald eagles).

- Focus on bird species of concern for evaluating waterfowl consumption advisories (i.e., mallard duck).

- Do not conduct air monitoring as part of the long-term monitoring program. It does not directly relate to the project RAOs, but may be included during remedial design efforts to assess downstream transport of PCBs via volatilization and atmospheric deposition.

- Coordinate data management efforts with other regional monitoring programs to build a comprehensive multi-media database of the project area that is accessible and usable by multiple parties.

4.4 Consistency with the Lake Michigan Lake-wide Management Plan (LaMP)

The Lake Michigan LaMP was created under the auspices of the Great Lakes Water Quality Agreement between the United States and Canada to restore and protect the integrity of the Lake Michigan ecosystem through collaborative, placed-based partnerships. The document was initially created in 1993 by an EPA-directed committee comprised of local and state governments, national trustees, industry, environmental groups, fishers, academia, and native tribes. The plan is considered a working document that will be revised every 2 years based on new findings and public discussion. Lake Michigan has 10 designated AOCs that have contributed toxic contaminants to the Lake Michigan watershed and the degradation of aquatic life. These 10 AOCs, including the Lower Fox River, have been designated as top priority areas where ecosystem management of contaminants and stressors must occur.

Under this program, the Lake Michigan Monitoring Coordination Council was established to provide a forum for coordinating and supporting monitoring activities in the Lake Michigan basin and to develop a shared resource of information, based on accepted standards and protocols, that are usable across agency and jurisdictional boundaries (EPA, 2000a). This council is currently analyzing data collected from an inventory of monitoring programs in the Lake Michigan Basin to determine whether the current monitoring coverage is sufficient to support indicators proposed in the Lake Michigan LaMP. A summary of the proposed indicators are presented in Table 4-1 as they relate to the valued ecological endpoint criteria including: fish community structure and function, fish habitat, and exotic species. The table also lists the metrics to be measured, the parameters for measurement, and the objectives/expectations for each of the valued endpoints.

These endpoints were identified in the Lake Michigan LaMP as important long-term management goals for contaminated sediment projects contributing to the Lake Michigan receiving water body. These goals will help the Fox River and

Green Bay remediation project formulate a long-term monitoring plan that will be consistent with Lake Michigan's long-term management strategies.

4.5 Final Selection of Monitoring Plan Elements

Post-project monitoring plan elements commonly implemented on contaminated sediment management and remediation projects can be summarized into physical, chemical, and biological components including:

- Physical
  - Bathymetry and side-scan sonar surveys
  - Underwater video surveys
  - Sediment characteristics

- Chemical
  - Surface water and groundwater for chemical analyses
  - Suspended and bedded surface sediment for physical and chemical analyses
  - Subsurface sediment cores for chemical analyses
  - Air samples for chemical analysis (usually collected during implementation)

- Biological
  - Benthic biota population and community studies
  - Resident and caged fish tissue for chemical analyses
  - Resident fish observations for physical deformities and histopathology
  - Caged mussels for chemical analyses (usually collected during implementation)
  - Sediment and water column acute and chronic toxicity testing
  - Bird tissue and eggs for chemical analyses
  - Bird observations for physical deformities and sublethal effects
  - Fish tissue for enzymatic indicators
  - Plant assemblage and coverage
  - Plant tissue for chemical analyses

4.5.1 Selection Factors

the possible types of monitoring plan elements listed above, monitoring methods considered most valuable for: 1) documenting contaminant reduction changes in the Lower Fox River and Green Bay, and 2) measuring achievement of the project RAOs will be selected. Final selection of monitoring elements were screened using the five management factors put forth by the sediment systems review committee organized by the Marine Board of the National Research Council. Committee members were selected to ensure a wide range of expertise needed to include a broad spectrum of viewpoints (academic, industry, laboratories, and public agencies). The committee was asked to evaluate and make recommendations to improve the usefulness of monitoring information (NRC, 1990). The five management factors initially described by the National Research Council during their assessment of marine environmental monitoring programs (NRC, 1990) include:

- Simplicity and affordability,
- Comparability against regulatory standards or other significant criteria,
- Implementable and appropriate for the site,
- Social relevance or importance, and
- Ability to be understood by laymen.

In the NRC document titled *Managing Troubled Waters: The Role of Marine Environmental Monitoring*, these factors are loosely defined as fundamentals of a sound program design which are required for successful implementation. Simple refers to a program that is sufficiently flexible to allow for modifications when changes in conditions or new information suggests the need. Affordable refers to a program that has adequate resources not only for the data collection efforts, but allows for detailed analysis and evaluation over the long term. The monitoring program should integrate the regulatory, data, and management needs and responsibilities with the local, state, regional, and federal agencies to optimize use of available resources. Comparability refers to a program where the data gathered can have adequate management, synthesis, interpretation, and analysis. Adequate interpretation generally requires comparison to a regulatory or site-specific standard, reference data, or baseline conditions. The monitoring program should be integrated into the decision-making system, with the decision points and feedback loops clearly established before the data are collected (NRC, 1990).

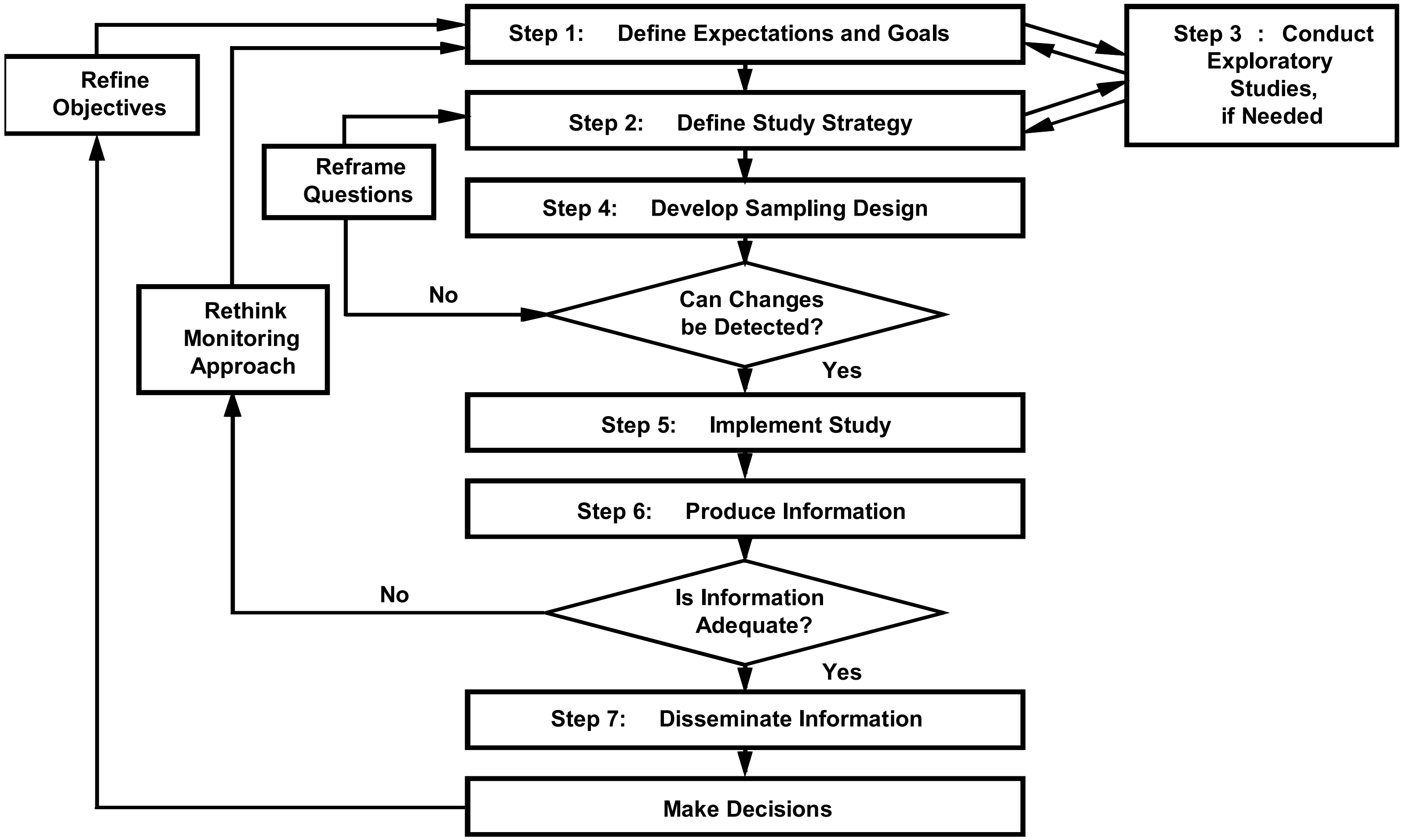
Implementability and appropriateness refers to a program in which the monitoring program can answer the questions being posed, a quality assurance program can be applied, and the data can be interpreted. The goals established should be achievable scientifically, technologically, logistically, and financially (NRC, 1990). Social relevance refers to a program in which the goals and objectives of the monitoring program can be clearly articulated in terms that pose questions that are meaningful to the public. The public generally understands fish tissue concentrations, and perhaps surface water concentrations. Most anglers and local residents want to know: "Can I eat the fish?" "Can I eat the birds?" and "Can I swim in the water?" Ability to be understood by laymen refers to a program where the information is made available to all interested parties in a form that is useful and meaningful to them. These generally include numerical and quantifiable data. Although these management factors are somewhat subjective without well-defined scales of measurement, they provide a useful and relative tool for comparison between different monitoring elements.

The monitoring elements retained after the screening process (compared to our five management factors) are presented in Table 4-2. Elements that met at least 50 percent of the valued factors criteria were retained for further consideration in the Lower Fox River monitoring plan. Surface and subsurface sediment chemistry along with resident fish tissue analyses were among the most commonly implemented measurement endpoints used in the majority of projects reviewed. In addition, these monitoring elements were often measured regardless of the type of remedy selected (removal, isolation, or natural recovery) ensuring their appropriateness to the Lower Fox River and Green Bay project, which will likely have a combination of selected alternatives. The final step in the selection process was to ensure that the retained monitoring elements were diverse in nature and output in order to verify achievement of (or progress towards) the project RAOs. As discussed in the following section, each one of the retained monitoring elements will be used to assess one or more of the project RAOs.

4.5.2 Results

The monitoring elements retained for the long-term monitoring plan (Table 4-2) include: surface water, surface sediment, fish tissue, bird tissue, bird reproductive assessment, and mammal reproductive assessment. Although the monitoring elements for mammals did not satisfy at least three factors (minimum needed for retainment), it was considered a significant data gap and a sensitive receptor identified in the project food web model. A few other monitoring elements, such as groundwater and sediment cores, will be utilized specifically for construction monitoring of engineered CDFs and sediment caps, and are not included in this long-term monitoring plan.

Figure 4-1 Flow Chart for Designing and Implementing a Monitoring Program



Source: *Managing Troubled Waters: The Role of Marine Environmental Monitoring* (NRC, 1990).

Table 4-1 Lake Michigan Lake-wide Management Plan (LaMP) Expectations

Ecological Criteria and Beneficial Use Impairments	Objectives/Expectations	Metrics to be Measured	Criteria for Measurement	Baseline Data	Status
Fish Community Structure and Function	To restore and maintain the biological integrity of the fish community so that production of desirable fish is sustainable and ecologically efficient.				
	Salmonines: Maintain a diverse salmonine community consisting of both wild and planted fish, and capable of sustaining an annual harvest of 6 to 15 million pounds, of which 20% to 25% is lake trout.	Standing stock (biomass) of salmonines.	A predicted standing stock of salmonines ranging from about 21 to 58 million pounds (Lake Michigan Salmonine Stocking Task Group, 1998, CONNECT model).	Based upon historical yields of native lake trout, a range in catch of about 5.7 to 7.3 million pounds annually is considered to be a minimum measure of the lake's capacity to yield salmonines; the theoretical maximum yield has been estimated at about 15.4 million pounds (*Fish Community Objectives for Lake Michigan*, Eshenroder *et al.*, 1995, GLFC).	Current standing stock biomass of salmonines is thought to be about 65 million pounds (Salmonine Stocking Task Group, 1998. CONNECT model).
	Establish self-sustaining lake trout populations.	Percentage of unmarked lake trout in assessment and sport catches.	The percentage of unmarked lake trout in assessment and sport catches is increasing towards 100% (all stocked lake trout are marked).	The percentage of unmarked lake trout in lake-wide assessment catches has ranged from 0% to 8.8% since the mid-1980s without an apparent trend.	No recruitment from natural reproduction is occurring and the lake trout population is comprised entirely of stocked fish.

Table 4-1 Lake Michigan Lake-wide Management Plan (LaMP) Expectations (Continued)

Ecological Criteria and Beneficial Use Impairments	Objectives/Expectations	Metrics to be Measured	Criteria for Measurement	Baseline Data	Status
Fish Community Structure and Function (Continued)	Enhance natural reproduction of coho and chinook salmon, and rainbow and brown trout.	Proportion of unmarked salmon and trout in assessment and sport catches (**a known portion of each species must be marked prior to release**).	Stable or increasing numbers of naturally-produced fish from each species.	Naturally-produced chinook comprised an estimated 32% of the 1990–1993 cohorts in Michigan waters; naturally-produced coho comprised an estimated 9.3% of the 1979 lake-wide sport catch; naturally-produced rainbow trout (steelhead) comprised 6% to 18% of annual smolt production in Michigan streams in the 1980s.	Coho and chinook salmon, rainbow and brown trout are naturally-reproducing in some watersheds tributary to the lake. The Michigan DNR has estimated that from 2.2 to 2.7 million chinook smolts have been produced annually in the 1990s as compared to 0.6 to 0.8 million in the 1970s (Salmonine Stocking Task Group, 1998).
	Planktivores: Maintain a diversity of prey species at population levels matched to primary production and to predator demands; expectations are for a lake-wide planktivore (alewife, smelt and bloater) biomass of 1.2 to 1.7 billion pounds.	Lake-wide biomass estimates of alewife, smelt and bloater.	Alewife, smelt and bloater in varying proportions constitute the bulk of the prey fish biomass; biomass size-spectrum models suggest that a total biomass of planktivores amounting to 1.2 to 1.7 billion pounds is a reasonable range for Lake Michigan (*Fish Community Objectives for Lake Michigan*, Eshenroder *et al.*, 1995, GLFC).	Lake-wide planktivore biomass estimates (portion of population available to bottom trawls) since 1973 have increased from 0.14 to 0.88 billion pounds as the dominant planktivore shifted from alewife to bloater (USGS-BRD); **catches in bottom trawls represent only a portion of prey fish biomass and will therefore always be lower than the actual biomass**.	The 1996 lake-wide planktivore biomass estimate was 0.65 billion pounds from bottom trawls (Note: studies are needed to understand how shifts in species composition affect biomass estimates, and the relationship between trawl catches and total biomass).

Table 4-1 Lake Michigan Lake-wide Management Plan (LaMP) Expectations (Continued)

Ecological Criteria and Beneficial Use Impairments	Objectives/Expectations	Metrics to be Measured	Criteria for Measurement	Baseline Data	Status
Fish Community Structure and Function (Continued)	Inshore Fishes: Maintain self-sustaining stocks of yellow perch, walleye, smallmouth bass, esocids, catfish and panfish; expected annual yields are 2 to 4 million pounds for yellow perch and 0.2 to 0.4 million pounds for walleye.	Indices of relative abundance (CPUE).	CPUEs for yellow perch and walleye capable of sustaining the expected ranges of annual yield have not been calculated and must be derived from lake-wide assessment data.	The Lake Michigan fishery management agencies are in the process of developing a lake-wide assessment plan which will include yellow perch and walleye, as well as other inshore species.	Self-sustaining populations of all these species exist, however, the relative abundance of yellow perch declined an estimated 90% in the southern portion of the lake from 1990 to 1996.
	Benthivores: Maintain self-sustaining stocks of whitefish, sturgeon, suckers and carp; expected annual yield of lake whitefish is 4 to 6 million pounds.	Indices of relative abundance (CPUE).	CPUEs for lake whitefish capable of sustaining the expected range of annual yield have not been calculated and must be derived from lake-wide assessment data.	The Lake Michigan fishery management agencies are in the process of developing a lake-wide assessment plan which will include lake whitefish, as well as other benthivores.	Self-sustaining populations of all these species exist, however, the lake sturgeon and longnose sucker are still listed as protected within the basin.
	Maintain a self-sustaining burbot population compatible with the rehabilitation and self-sustainability of lake trout.	Relative abundance indices (CPUE).	A ratio of relative abundance of lake trout to burbot at about 3.5:1 in the southern portion of the lake and 1:1 in the northern portion.	Historical catches of native lake trout and burbot in small mesh gill nets fished lake-wide for chubs by the vessel *Fulmar* (U.S. Bureau of Fisheries) in 1931–1932 suggest mean ratios of 3.5 lake trout per burbot in southern waters and a 1 to 1 ratio in northern waters.	Current ratios have not been available from annual stock assessments, but will be as the new lake-wide assessment plan is implemented; studies comparing the catchability of these two species are needed to evaluate th reliability of using the proposed ratios.

Table 4-1 Lake Michigan Lake-wide Management Plan (LaMP) Expectations (Continued)

Ecological Criteria and Beneficial Use Impairments	Objectives/Expectations	Metrics to be Measured	Criteria for Measurement	Baseline Data	Status
Fish Community Structure and Function (Continued)	Other Species: Protect and sustain a diverse community of native fishes including species such as cyprinids, gar, bowfin, brook trout, sculpins and others not previously mentioned.	Species richness.	A species is considered to be present in the lake if at least one individual (any life stage) is captured.	By 1970, five species of deepwater ciscoes had been extirpated from the lake as well as the paddlefish (*Fish Community Objectives for Lake Michigan*, Eshenroder *et al.*, 1995, GLFC); lake herring and emerald shiner populations also have never recovered to their historical levels of abundance.	A total of 92 species are known to occur in the lake proper, of which 75 are native and 13 are naturalized (*Fish Community Objectives for Lake Michigan*, Eshenroder *et al.*, 1995, GLFC).
	Sea Lamprey: Suppress the sea lamprey to allow the achievement of other fish community objectives.	Wounding rates on lake trout.	A lake-wide mean wounding rate not greater than 5 per 100 lake trout of all sizes.	The 1984–1996 mean wounding rate was 4 per 100 trout, but has generally been increasing since 1987 (*Sea Lamprey Wounding of Lake Trout in Lake Michigan*, Ebener, 1997, GLFC).	The lake-wide mean wounding rate was 5 per 100 lake trout in 1996.

Table 4-1 Lake Michigan Lake-wide Management Plan (LaMP) Expectations (Continued)

Ecological Criteria and Beneficial Use Impairments	Objectives/Expectations	Metrics to be Measured	Criteria for Measurement	Baseline Data	Status
Fish Habitat	Protect and enhance fish habitat and rehabilitate degraded habitats, including historic riverine spawning and nursery areas fo anadromous species.	Measure key features of the physical (substrate, water depth), chemical (dissolved oxygen, total phosphorus), and biological (vegetation) components of aquatic habitats.	A formal process such as the Classification and Inventory of Great Lakes Aquatic Habitats (CIGLAH) should be considered to classify and inventory habitats in the lake basin.	Inventories have been compiled on the general locations of many important fish spawning habitats in Lake Michigan (*Atlas of the Spawning and Nursery Areas of Great Lakes Fishes*, Vol. IV, Goodyear *et al.*, 1982, USFWS), but specific locations, habitat characteristics (e.g., chemical and biological features), and current status has not been addressed but for a few spawning shoals for lake trout.	The classification, location, and status of important fish habitats in Lake Michigan has not been addressed in a comprehensive fashion.

Table 4-1 Lake Michigan Lake-wide Management Plan (LaMP) Expectations (Continued)

Ecological Criteria and Beneficial Use Impairments	Objectives/Expectations	Metrics to be Measured	Criteria for Measurement	Baseline Data	Status
Exotic Species	Minimize the unintentional introduction of new exotic species and the spread of existing exotics that may negatively impact the structure and function of existing fish communities.	The appearance of new exotic species and the expansion in range (number of locations) of existing exotic species.	An exotic species is considered to be present in the lake or in a specific area if at least one individual of any life stage is captured.	Since the 1800s, some 136 non-indigenous aquatic organisms have become established in the Great Lakes (*Exotic Species in the Great Lakes: A History of Biotic Crises and Anthropogenic Introductions*, Mills *et al.*, 1991, GLFC); most of these have come from Europe (47%), the Atlantic Coast (18%), and Asia (14%), and the rate of introduction has increased as the rate of human activity has increased; more than one-third of the organisms have been introduced in the past 30 years, coincident with the opening of the St. Lawrence Seaway in 1959.	Although various ballast water and aquaculture control measures, and importation and possession bans (bait buckets, pet stores) have been implemented at the state, provincial and federal levels to address potential pathways for the unintentional introduction of exotic species, the appearance of new introductions and range expansion of existing exotics remains a constant threat, and a vigilant watch must be kept throughout Lake Michigan.

Table 4-1 Lake Michigan Lake-wide Management Plan (LaMP) Expectations (Continued)

Chapter 2	Chapter 3		Chapter 4 Lake Michigan LaMP: Current Status of the Ecosystem,	Chapter 5 Lake Michigan Stressor Sources and Loads	Chapter 6	
Lake Michigan LaMP: Vision, Goals and Ecosystem Objectives	**Indicators and Monitoring of the Health of the Lake Michigan Ecosystem**				**Strategic Action Agenda: Next Steps**	
Endpoint Goal	**Monitoring**	**Human Activity**			**Means to an End Goal**	**Recom-mendations**
1. We can all eat any fish.	• Chemical contamination in fish • Site assessments • Eagle reproduction	• Fish advisories • Congressional reports on ▸ Great Water ▸ Mercury ▸ Dioxin				
2. We can all drink the water.	• Raw water quality data • Source water assessments	• Water utility notifications • Source water protection				
3. We can all swim in the water.	• E Coli levels in recreational water	• Beach closing advisories • State 305(b) WQ reports				
4. All habitats are healthy, naturally diverse and sufficient to sustain viable biological communities.	• Fish assessments • Bird counts • Wetlands inventories and assessments • Stream flows • Eco-rich area assessments	• Endangered species list • Wetland mitigation and protection • Zoning • Fish stocking • Fish refuges • USFWS refuges • Ballast water exchange • Dune protection • Eco-rich cluster map				
5. Public access to open space, shoreline and natural areas is abundant and provides enhanced opportunities for human interaction with the Lake Michigan ecosystem, aquatic habitat and biological population.	• Urban density • Coastal parks acreage • Conservation easements	• Open space funding and protection statutes • Coastal zone management				
6. Land use, recreation and economic activities are sustainable and support a healthy ecosystem.	• Contaminants in recreational fish • Sustainable forests • Land conversion	• Superfund cleanups dredging • CRP percent of eligible farm lands • Brownfields to greenfields redevelopment				

Table 4-2 Selection of Monitoring Program Elements Using Five Management Factors

Monitoring Element	Management Factors [4]					Retain
	Simple and Affordable	Comparable to Standards	Appropriate to Site	Socially Important	Clear to Layman	
Surface Water	Yes	Yes	Yes	Yes	Yes	Yes
Groundwater [1]	Yes	Yes	Unknown	No	Yes	Yes [1]
Surface Sediment	Yes	Yes	Yes	No	Yes	Yes
Sediment Cores [2]	Yes	Yes	Yes	No	Yes	Yes [2]
Benthic Abundance	Yes	No	No	No	No	No
Fish Tissue	Yes	Yes	Yes	Yes	Yes	Yes
Fish Deformity	Yes	No	No	No	Yes	No
Toxicity Test	Yes	Yes	Yes	No	No	No
Bird Tissue	No	Yes	Yes	Yes	Yes	Yes
Bird Deformity	No	No	No	No	Yes	No
Bird Reproductive Assessment	Yes	No	Yes	No	Yes	Yes
Mammal Tissue	No	No	Yes	Yes	No	No
Mammal Reproductive Assessment	Yes	No	Yes	No	No	No [3]
Habitat Assessment	Yes	No	Yes	No	No	Yes [3]
Enzyme Test	Yes	No	NA	No	No	No
Plant Assemblage	No	No	No	No	No	No
Plant Tissue	Yes	No	Yes	No	No	No

Notes:

1 Groundwater will be monitored in areas where CDFs are installed.
2 Sediment cores will be advanced in areas where sediment caps are placed.
3 Retained for the long-term monitoring plan for mink because it is a significant data gap and a valued receptor.
4 Management factors derived from NRC 1990 document *Managing Troubled Waters: The Role of Marine Environmental Monitoring*.

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5 Model Long-term Monitoring Plan for the Lower Fox River and Green Bay

This section presents the proposed model long-term monitoring plan for the Lower Fox River and Green Bay RI/FS remediation project. The focus of this document was to design a post-project, long-term monitoring plan based on project expectations, valued endpoints, a review of national and regional monitoring programs, case study precedent, lessons learned, guidance documents, and scientifically-based recommendations. The plan was formulated around achievement of the five RAOs listed in the Lower Fox River and Green Bay feasibility study. A summary of the monitoring plan elements selected for verification of long-term RAOs (RAO-1 through RAO-4) are presented in Table 5-1. RAO-5 is not included in this model plan. Table 5-2 presents a summary of the monitoring elements proposed for long-term monitoring.

In sequential order, this section: 1) summarizes the long-term project RAOs and their associated expectations, 2) discusses the timing and onset of long-term monitoring between different reaches and zones, and 3) presents the monitoring elements (surface water chemistry, sediment chemistry, fish tissue, bird tissue, invertebrate tissue, and reproductive assessments) that will be used to verify achievement of the long-term RAOs. Sampling methods for each monitoring element are described in some detail regarding the frequency, number of samples, location, species selection, and chemical analyses.

5.1 Plan Overview

5.1.1 Defining the Remedial Action Objectives and Expectations

As described in the previous chapters, this long-term monitoring plan is designed to verify achievement of the project RAOs and to monitor the integrity of the physical, chemical, and biological components of the aquatic system. The five RAOs defined for the Lower Fox River and Green Bay project can be translated into expectations and viable measurement endpoints that lay the groundwork for developing a long-term monitoring plan. The project expectations that correlate to the defined RAOs for the Lower Fox River and Green Bay include:

RAO	Expectation	Lower Fox River	Green Bay
Surface Water Quality	Reduction in contaminant concentrations in suspended sediments and surface water	✓	✓
Human Health	Reduction in contaminant concentrations in fish and waterfowl consumed by humans	✓	✓
Health of Environment	Reduction in contaminant concentrations in fish, piscivorous birds, benthos, and mammals	✓	✓
Sediment Transport	Reduction in contaminant loading to Green Bay		✓
Minimize Contaminant Releases	Maintain low contaminant concentrations in surface water during active remediation (short-term)	✓	✓

More specifically, project expectations include the following:

- Remediation will be completed within 10 years;
- Surface water quality will eventually meet background conditions;
- The removal of sport fish consumption advisories will be achieved within 10 years after remediation (in 20 years);
- The removal of all fish consumption advisories within 20 years after remediation (in 40 years);
- The removal of all waterfowl consumption advisories within 20 years after remediation (in 40 years).
- Resident bird populations will achieve sustainable reproductive viability when compared to reference sites;
- Resident fish, bird, and invertebrate populations will achieve safe levels of contaminants in tissue determined by risk-based models and state/federal criteria;
- Annual mass loading of contaminants from the Lower Fox River to Green Bay will not exceed the annual non-point source loading of PCBs and mercury to Green Bay and subsequent loading to Lake Michigan; and

- The plan should be compatible with other regional program objectives, and compliment the long-term goals of the Lake Michigan LaMP. A detailed design of the long-term monitoring program is presented in Table 5-2.

Most of the project RAOs (RAO-1 through RAO-4) address long-term goals that may require 20 to 40 years to achieve. This long-term monitoring plan was designed to address these RAOs. The RAO concerning "minimizing contaminant releases during active remediation" (RAO-5) is a short-term goal to be utilized during active remediation. This long-term monitoring plan does not address this short-term goal. Short-term goals will be used to confirm and verify success of an implemented active remedy, and will be important components of a well-defined remedial action plan for the Lower Fox River and Green Bay project. Short-term monitoring components will be discussed during development of a final remedial action plan and will likely include many elements discussed below.

5.1.2 Initiation of Long-term Monitoring

Long-term monitoring will begin after completion of an active remedy (removal or isolation) or after an area has been designated for monitored natural recovery instead of active remediation. Long-term monitoring is defined as sampling events that begin after post-project completion of a remedy or decision not to remediate. However, sampling data collected during a long-term monitoring program needs to be testable and comparable to pre-remedy conditions. In order to assess the spatial and temporal trends in contaminant concentrations, an adequate baseline data set should be developed. Therefore, the pre-remedy sampling event and the post-project verification sampling event should follow the same technical design as the long-term monitoring plan. Pre-remedy sampling is conducted to verify initial conditions immediately prior to remedy implementation. Post-project verification sampling is conducted to verify achievement of the remedy. While both of these monitoring plans may have a different scope and objectives than a long-term monitoring plan, they will serve as the baseline data set for subsequent long-term monitoring events. They should have, at a minimum, the same monitoring elements proposed in this long-term model. In areas designated for MNR, a pre-remedial baseline sampling event will be conducted for long-term monitoring comparisons. In summary, the baseline data set will be collected prior to initiation of active remediation (or initiation of MNR) and immediately after completion of a remedy for comparison with long-term monitoring elements.

For example, if the Appleton to Little Rapids Reach of the Lower Fox River has 10 years of active remediation planned, then long-term monitoring for that reach will not begin until after final completion of the remedy. If a deposit of contaminated sediment within that reach (identified in the FS) will not be remediated, then long-term monitoring of natural recovery for that deposit may begin at Time 0 while other deposits within the same reach are being remediated. The entire reach will not begin long-term monitoring for another 10 years, after completion of all active remediation within the reach. The extent of sampling within the reach will need to be coordinated within a reasonable effort, scope, and budget to ensure that contaminated deposits remaining in-place are not serving as new sources of recontamination and not contributing to contaminant transport to newly remediated areas.

For a second example, if Green Bay is monitored for natural recovery, then long-term monitoring for these areas begins at Time 0 although the Lower Fox River may undergo active remediation in some areas. The technical design of the river monitoring (during remediation) should be comparable to the bay monitoring over the same time period.

5.1.3 Scales of Measurement

Based on the complexity and duration of the proposed remediation plan for the Lower Fox River and Green Bay, the examples described above reinforce the need for defining different levels of monitoring. For the purposes of this project, three levels of monitoring are defined:

- **"Deposit-wide" Scale -** monitoring around a specific deposit, CAD site, nearshore fill, disposal site, or other physical feature generally confined to within a reach;

- **"Reach-wide" Scale -** holistic monitoring of a reach, generally at the end of a reach to measure transport of contaminants to the next reach, or for fish with home ranges spanning an entire reach; and

- **"River-wide" Scale -** monitoring of the Lower Fox River or Green Bay to compare differences between the river and bay system.

Most of the monitoring elements proposed in this plan are on the reach-wide scale. However, some of these elements may be considered river-wide or bay-wide (i.e., bald eagles or mink habitat) depending upon the final monitoring design. Elements may also be considered on a deposit-wide scale if active remedies are implemented at different times within a reach or if a unique physical feature warrants more detailed attention.

5.1.4 Limitations

The focus of this monitoring plan will be on verification of the valued endpoints and not on continued correlation analysis between physical and chemical components of the Lower Fox River system and observed effects. For example, one valued endpoint is protection of human health via consumption of resident fish in the Lower Fox River, so the monitoring plan will include fish tissue measurements of consumable fish species to verify protection of human health. The plan does not intend to use indicator variables such as sediment chemistry or water chemistry to imply protection of human health. Also, the plan does not intend to further develop a correlation analysis between sediment chemistry and fish tissue concentrations. However, sediments samples will be collected at specified intervals within each reach to assess sediment transport concerns and may be used to verify protection of pathway exposures to resident fish.

5.2 Monitoring Plan Approach

This proposed monitoring plan is designed to verify achievement of (or progress towards) attainment of the long-term project goals summarized as the RAOs. The proposed monitoring plan is organized into measurable physical, chemical, and biological elements that are used to assess the spatial and temporal trends towards these long-term goals. Monitoring plan elements include surface sediment chemistry; surface water chemistry; fish, bird, and invertebrate tissue analyses; and bird and mammal population counts (Tables 5-1 and 5-2). For FS cost estimates, all monitoring elements will be conducted for a period of 40 years, with sampling frequencies of every 5 years. Sampling frequencies and media may change after selection of the final remedy.

These elements are listed as a model framework of sampling methods for long-term monitoring on the Fox River and Green Bay, but are not intended to comprise detailed sampling and analysis design components. Specific management factors such as sample sizes, number of replicates, locations and chemical analysis will be finalized after completion of the RI/FS report and selection of environmental remedies.

Statistical models will be used to determine the appropriate sample sizes based on the desired power of detection (alpha and beta) and the confidence limits surrounding the data results (change of Type I and II errors). However, eight or nine fish samples will be expected per reach/zone. The sampling plan will be designed to minimize the influence of confounding factors and sampling variability as much as possible.

5.2.1 Monitoring for Surface Water Quality

Monitoring elements used to verify long-term achievement of surface water quality will consist of surface water samples collected from fixed locations over time. Collection of surface water samples at sediment remediation sites were used at several site-specific projects including United Heckathorn, Lake Jarnsjön, Minamata Bay, and James River, Virginia.

Surface water sampling will be conducted on a “reach-wide” scale at seven locations: one station in each river reach (4 locations), two stations in Green Bay—zones 2 and 3B (2 locations), and one station in Lake Winnebago. Water samples will be collected near the end of a reach or at fixed locations in a lake over time, to assess the net contribution of contaminated sediments located along each reach to the overlying surface water. The sampling frequency is modeled after the sampling scheme conducted for the Green Bay Mass Balance Study.

For the Green Bay Mass Balance Study, samples were collected intensively at numerous stations over a 1-year period (1989 and again in 1994) to quantify the maximum PCB mass loading during periods of maximum flow events. Since higher mass loading is expected during storm and rainfall events when river flow is highest, the sampling events were structured at monthly intervals during the wet season to predict flow variability and at daily intervals (as needed) during storm events to capture the highest possible PCB loading events. The 1-year sampling events were conducted every 5 years.

The focus of the Lower Fox River/Green Bay monitoring plan will be to assess temporal changes in surface water quality as opposed to horizontal and vertical spatial heterogeneity. Prior to long-term monitoring, pre-remedial and post-remedial baseline sampling will be conducted. Samples will be collected at designated intervals from March through November every 10 years. Several samples will be collected from within each reach/zone at fixed locations over time. Additional samples will be collected during periods of maximum flow events to capture the highest possible PCB-mass loading estimates. Samples will be analyzed for PCB congeners, co-planar PCB congeners, mercury, TSS, DOC and TOC for particulate and dissolved fractions (Table 5-2). Sample concentrations will be compared to project water quality criteria designed to be protective of human health (ingestion and dermal contact).

5.2.2 Monitoring for Protection of Human Health

Monitoring elements used to verify long-term achievement of “reduced potential for chemicals to cause adverse effects to human health” as stated in the Lower Fox River and Green Bay FS will consist of fish tissue sampling from specific reaches over time. Similar methods are described and/or recommended in regional monitoring programs (NOAA NS&T, SF-Bay Estuary and GLNP) and guidance documents, and were used on several Great Lakes projects (Sheboygan River, Waukegan Harbor, Grasse River, Ford Outfall, Collingwood Harbour) and other national and international projects (Bayou Bonfouca, GM Foundry, River Emån, Minamata Bay).

Fish Tissue Sampling

Fish tissue sampling will be conducted on a “reach-wide” scale within each reach of the Lower Fox River (4 regions) and within each zone of Green Bay (4 regions) to assess the uptake of contaminants into fish tissue. The reach-wide scale is appropriate since fish generally have large home ranges, the exact location of fish feeding grounds cannot be determined, and the reaches are separated by dams limiting the fish ranges. The focus will be to assess changes in fish bioaccumulation uptake within each reach over time. The long-term goal of the sampling program will be to support the removal of Wisconsin and Michigan state general fish consumption advisories currently in-place for numerous fish species (EPA, 2000d), assuming fish tissue concentrations show reduced PCB and mercury levels over time.

Resident fish samples will be collected in pre-remedial and post-remedial baseline sampling events, and every 5 years thereafter, after initiation of the long-term monitoring program. These will be concurrent with the surface water sampling years. At the 10-year mark, the sampling plan will be reevaluated based on the data collected. Fish species collected in the Lower Fox River will include resident walleye, carp, and white bass alewife. Discrete whole fish and skin-on-fillet samples will be analyzed for PCB congeners[1], mercury, and lipids. Fish species collected in Green Bay will include walleye, carp, lake trout, white perch, and white bass for the same analyses. The sampling design will include consistent seasonal sampling events, species, sizes, and age classes of fish to the best practicable extent. Three size classes of fish per fish species will be specified.

Bird Tissue Sampling

Bird tissue sampling will be conducted on a “reach-wide” scale within each zone of Green Bay (5 regions including Zone 1) to assess the uptake of contaminants into bird tissue. The reach-wide scale is appropriate since birds generally have large home ranges and the exact location of feeding grounds cannot be determined. The focus will be to assess temporal changes in bird chemical body burdens within each zone. The long-term goal of the sampling program will be to support the removal of the Wisconsin state waterfowl consumption advisory

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[1] PCB congeners include the Wisconsin State Laboratory PCB Congener List as well as co-planar dioxin-like PCB congeners.

currently in-place for mallard ducks, if bird tissue concentrations show reduced PCB levels over time.

Resident mallard duck samples and one other sensitive bird species (i.e., coots or mergansers) will be collected in pre-remedial and post-remedial baseline sampling events and every 5 years thereafter, after initiation of the long-term monitoring program and will be concurrent with surface water sampling events. At the 10-year mark, the sampling plan will be reevaluated based on the data collected. Samples will be analyzed for PCB congeners, mercury, and lipids. The sampling design will include consistent seasonal sampling events, species, sizes, and age classes of waterfowl to the best practicable extent. A minimum of one size class per bird species will be specified.

5.2.3 Monitoring for Protection of Environmental Health

Monitoring elements used to verify long-term achievement of environmental health defined as "the reduced potential for chemicals to cause adverse effects to environmental receptors," will consist of resident fish, invertebrate, and bird tissue sampling over time. Monitoring elements will also include reproductive observations such as number of nesting sites, number of eggs, and population counts for bird and mammal populations. Similar fish tissue monitoring methods were used in several national monitoring programs (NOAA NS&T, EMAP and GLNP) and on several Great Lakes projects (Sheboygan River, Waukegan Harbor, Grasse River, Ford Outfall, and Collingwood Harbour). Invertebrate mussel tissue monitoring was used in two regional monitoring programs (San Francisco-EP and EMAP). However, long-term bird tissue monitoring, bird population nor mammal population monitoring have not been documented in any regional, national, or site-specific monitoring programs reviewed.

Frequency of sample collection for all media will include pre-remedial and post-remedial baseline sampling events, and every 2 to 5 years for 10 years thereafter, after initiation of the long-term monitoring plan. At the 10-year mark, the sampling plan will be reevaluated based on the data collected. Sampling events will be concurrent with surface water sampling years. The final selection of sampling media and frequency will be revised after selection of the remedy and project expectations. For the purposes of the FS cost estimate, monitoring elements were sampled every 5 years for 40 years.

Fish Tissue Sampling

Fish tissue sampling will be conducted on a "reach-wide" scale. Samples will be collected for each river reach (4 regions) and each zone of Green Bay (4 regions—zones 2, 3A, 3B, and 4) to assess the bioaccumulation of contaminants in resident fish. The focus will be to assess temporal changes in contaminant uptake over time and spatial variability between reaches and zones. The long-term goal of the sampling program will be to verify if resident fish tissue concentrations are below screening levels determined to be protective of sublethal fish effects such as growth, health, and reproductive potential.

Resident fish samples will be collected in pre-remedial and post-remedial baseline sampling events, and every 5 years thereafter, after initiation of the long-term monitoring program and will be concurrent with the surface water sampling years. Resident fish species collected in the Lower Fox River and Green Bay will include: walleye, carp, perch, emerald shiners, gizzard shad, and alewife. Discrete, adult, whole fish samples will be analyzed for PCB congeners, mercury, DDE and lipids, except shiners and shad will be collected as composites. Young-of-the-year fish samples will also be collected for walleye and gizzard shad as 25-fish composites. The sampling design will include consistent seasonal sampling events, species, sizes, and age classes of fish to the best practicable extent. The length, weight, and sex of each fish will be recorded during collection. A minimum of one size class will be specified per fish species.

Invertebrate Tissue Sampling

Invertebrate tissue sampling will be conducted on a "reach-wide" scale. Samples will be collected from each river reach (4 regions) and each zone of Green Bay (4 regions) to assess the bioaccumulation of contaminants in resident zebra mussels and/or caged mussels. The focus will be to assess temporal changes in contaminant uptake from fixed locations over time and spatial variability between reaches and zones. The long-term goal of the sampling program will be to determine the rate of decline in PCB concentrations to sessile invertebrate organisms.

Resident zebra mussel samples or caged mussel samples will be collected in pre-remedial and post-remedial baseline sampling events and every 5 years thereafter, after initiation of the long-term monitoring program, and will be concurrent with the surface water sampling years. Resident whole body composite samples will be analyzed for PCB congeners, mercury, DDE and lipids. Statistical models will be used to determine the appropriate samples sizes, however, a minimum of seven composite samples will be expected per reach/zone for a total of 70 samples per sampling year. The size, location, and weight of each sample will be recorded during collection.

Although an extensive zebra mussel data set does not exist for the Lower Fox River and only one year of sampling has been conducted in Green Bay, zebra mussels will serve as a good indicator of PCB bioaccumulation potential for benthic organisms with small home ranges. Zebra mussels were specifically selected because they are relatively large with adequate tissue volume for analysis, they are found in all reaches of the Lower Fox River and Green Bay, they are easy to collect, and they readily uptake PCB contaminants after exposure. Caged mussels would also serve as valuable indicators of PCB exposure and uptake with minimal interference from the inherent site variability often associated with resident species.

Piscivorous Bird Tissue Sampling

Bird tissue sampling will be conducted on a "reach-wide" scale. Piscivorous bird tissue samples will be collected from each zone of Green Bay (5 regions—zones 1, 2, 3A, 3B, and 4) to assess changes in contaminant exposure and uptake by resident double-crested cormorants from fixed areas over time. The focus will be to assess temporal changes in contaminant uptake from fixed locations over time and spatial variability between reaches and zones. The long-term goal of the sampling program will be to verify if resident bird populations exhibit reduced exposure from site contaminants. Resident double-crested cormorants will serve as surrogate indicators of PCB exposure and uptake over time. However, they will not serve as good indicators of residual risk to other sensitive bird species (i.e., Forster's terns) since current populations are rapidly recovering and reproductive rates are not correlated to PCB levels (Custer *et al.*, 1999).

Bird tissue samples will be collected in pre-remedial and post-remedial baseline sampling events and every 5 years thereafter, after initiation of the long-term monitoring program and will be concurrent with the surface water sampling years. Discrete resident whole body samples will be analyzed for PCB congeners, mercury, DDE, and lipids.

Bald Eagle Tissue Sampling

Raptor egg and blood plasma sampling will be conducted on a "river-wide" scale. Samples will be collected from two sites along the Lower Fox River (2 locations) and two sites along the shores of Green Bay (2 locations) to assess the bioaccumulation of contaminants in resident bald eagles. The focus will be to assess temporal changes in contaminant uptake from fixed locations over time and spatial variability between the river and bay. The long-term goal of the sampling program will be to verify if the resident populations are at risk from PCB uptake. The location and number of sampling sites will be dependent upon field observations and the stability of the population, and may vary between sampling events. Sampling will be consistent with the previous work performed by Dykstra and Meyer (1996).

Bald eagle samples will be collected every 5 years after initiation of the long-term monitoring program and will be concurrent with surface water sampling years, if possible. Whole body egg and blood plasma samples will be analyzed for PCB congeners, mercury, and DDE. If possible, two or three field replicates per nest will be collected. In addition to whole body chemical analyses, a population assessment will be conducted during field collection events. This data will build upon the existing bald eagle tissue already recorded in the Fox River database and will be a continuation of WDNR sampling programs.

Bird Reproductive Assessment Monitoring

Nesting counts will be conducted on a "bay-wide" scale for double-crested cormorants and a "river-wide" scale for bald eagles during collection of tissue data. The focus will be to assess temporal changes in reproductive viability and population stability from fixed locations over time. The long-term goal of the sampling program will be to verify if the resident populations are increasing/declining. At each sampling station, the number of occupied/unoccupied nests and the number of eggs per nest will be recorded. Population counts will be collected every 5 years, concurrent with the tissue collection events. These data sets will build upon the existing double-crested cormorant and bald eagle data already recorded in the Fox River database and will be a continuation of WDNR sampling programs.

Mammal Habitat Evaluation

Mammal population assessments will be conducted on a "reach-wide" scale. The assessment will be conducted from multiple sites along the shores of Lower Fox River and Green Bay to assess the presence/absence of mink or river otter populations in the project area. Mink are predatory, semiaquatic mammals generally associated with stream and river banks, lake shores, and freshwater marshes (USFWS, 1986). Mink are known to readily bioaccumulate PCBs via consumption of fish, their main dietary staple. The focus will be to establish baseline conditions and assess temporal changes in population sustainability from fixed locations over time and spatial variability between the river and bay. A future long-term goal of the sampling program may be to verify if the resident populations are present in the project area after habitat suitability has been determined. The location and number of sampling sites will be dependent upon field observations and the site access, and may vary between sampling events.

Mink habitat assessments will be conducted every 5 years after initiation of the long-term monitoring within each river reach. The USFWS habitat suitability index model for mink (USFWS, 1986) will be used to: 1) first determine where suitable habitats exist along the shoreline of the Lower Fox River and Green Bay, then 2) observe each suitable habitat for presence/absence of mink populations.

5.2.4 Monitoring for Sediment Transport

Monitoring elements used to verify long-term achievement of "reduced potential for future transport of PCBs from the Lower Fox River to Green Bay" as defined in the Lower Fox River FS will consist primarily of water column sampling, surface sediment sampling, and bathymetry over time. Similar monitoring methods were used on almost every site-specific sediment remediation project reviewed, and many of the regional monitoring programs.

Water Column Sampling

Surface water column sampling will be conducted on a "reach-wide" scale in a combined effort with verification of surface water quality. The sampling frequency and technical design is modeled after the Green Bay Mass Balance Study. These samples will also serve as useful indicators of potential downstream transport of contaminants and mass-loading estimates.

Surface Sediment Sampling

Surface sediment sampling (0 to 10 cm) will be conducted on a "reach-wide" scale to primarily assess the potential downstream transport of contaminants to areas without active remediation. Areas selected for passive remediation will be monitored over time for attenuation, diffusion, dispersion, or burial of contaminants and are referred to as monitored natural recovery (MNR) areas. Sampling locations will be placed at fixed locations in depositional areas and will include six locations per river reach (24 locations) and six locations per zone in Green Bay—zones 2, 3A, 3B, and 4 (24 locations). The focus of this monitoring effort will be to verify that physical processes are decreasing the levels of PCBs, DDE and mercury in surface sediments over time via sediment burial, and chemical recovery.

Sediment samples will be collected every other year for the first 10 years following a baseline sampling event, and will coincide with surface water sampling years. At the 10-year mark, the sampling plan will be reevaluated based on the data collected. Sediment (0 to 10 cm) will be collected as discrete samples and submitted for physical (grain size and TOC) and chemical testing (PCB congeners, DDE, and mercury).

Bathymetry

Bathymetric soundings will be conducted every 3 to 5 years for the first 10 years. At the 10-year mark, the sampling plan will be reevaluated based on the data collected. This effort will compliment the USACE annual assessment of shoaling in the navigational channels of De Pere to Green Bay Reach and Green Bay Zone 2. Survey locations will include transects running perpendicular and parallel to shoreline and include a bisect of the Lower Fox River from one shoreline to the other. Survey locations will include areas of active remediation in addition to areas designated as MNR to assess potential scouring events that may inadvertently cause significant resuspension and downstream transport of residual contaminants in the surface and subsurface sediments.

5.2.5 Monitoring for Potential Contaminant Releases During Active Remediation

Potential releases of contaminants during active remediation (project RAO 5) is a short-term goal that will be covered during development of deposit-specific and/or reach-specific remediation and monitoring plans. An adequate verification sampling program will be developed as part of each selected remedy to verify the implementability and success of a selected remedial action. These programs will likely include many of the same monitoring elements selected for the long-term monitoring program. However, this long-term monitoring plan is not designed or intended to address contaminant releases during remediation.

Table 5-1 A Summary of Monitoring Elements for Verification of Project RAOs

Remedial Action Objective Lower Fox River and Green Bay	Proposed Monitoring Program Elements Used to Determine Verification of RAOs							
	Physical	Chemical [1]		Biological				
	Bathymetry	Surface Water	Surface Sediment	Fish Tissue	Invertebrate Tissue	Bird Tissue or Eggs	Bird Nest Counts	Mink Counts
1 Achieve, to the extent practicable, **surface water quality** throughout the Lower Fox River and Green Bay.		◆						
2 Protect **humans** who consume fish from exposure to COCs that exceed protective levels.				◆		◆		
3 Protect **ecological receptors** from exposure to COCs above protective levels.		◆	◆	◆	◆	◆	◆	◆
4 Reduce **transport of PCBs** from the Lower Fox River into Green Bay and Lake Michigan.[2]	◆	◆	◆					
5 Minimize the downstream movement of PCBs during implementation of the remedy.[3]	◆	◆	◆					

Notes:

[1] Sediment traps and air sampling stations were not included in the chemical list because they are not proposed monitoring elements in the long-term monitoring plan.

[2] The long-term monitoring plan does not discuss nor include verification of isolation and source control of sediment caps, CADs, and CDFs.

[3] RAO 5 is not included in the long-term

Table 5-2 Proposed Long-term Monitoring Plan for the Lower Fox River and Green Bay

RAO	Monitoring Element	Sample Type	Location [4, 5]	Frequency	Years with Historical Data	Expected Duration Over Time [2]	Analyses [3, 6]
Surface Water Quality (RAO 1)	Water column [1]	Depth composite sample through water column; fixed locations over time.	One station at end of each reach in LFR (4 stations), two stations in Green Bay - zones 2 and 3B (2 stations), and one station in Lake Winnebago (1 station) to quantify input loads.	Intensive sampling every 10 years with numerous samples collected over the year from each reach/zone. Collect most samples from March through November, with additional samples (up to 10) during periods of max flow events (approx. N = 20 per reach).	1989/1990 1994/1995	40 years	PCB congeners, coplanar congener PCBs, mercury, TSS, DOC, TOC; particulate and dissolved fractions.
Human Health (RAO 2)	Fish tissue (in LFR)	Resident whole fish and skin-on-fillet for walleye, carp, and white bass. Discrete samples.	Collect discrete samples from each reach. Rely on statistical models to determine sample sizes (approx. N = 8 per reach).	Every 5 years and concurrent with water sampling years.	1976–1998	40 years	PCB congeners, mercury, lipids
	Fish tissue (in Green Bay)	Resident whole fish and skin-on-fillet for walleye, carp, lake trout, white perch, and white bass. Discrete samples.	Collect discrete samples from each zone (zone 2, 3A, 3B and 4). Rely on statistical models to determine sample sizes (approx. N = 8 per zone).	Every 5 years and concurrent with water sampling years.	1976–1998	40 years	PCB congeners, mercury, lipids
	Waterfowl bird tissue	Resident whole body and breast for mallard ducks and one other bottom-feeding duck species (mergansers). Discrete samples.	Collect discrete samples from each zone. Rely on statistical models to determine sample sizes (approx. N = 8).	Every 5 years and concurrent with water sampling years.	1987	40 years	PCB congeners, mercury
Environment Health (RAO 3)	Fish tissue	Whole body for food web model fish (walleye, carp, emerald shiners, gizzard shad, alewife). Discrete samples except YOY. Collect YOY (for walleye and gizzard shad) as 25 fish composites.	Collect discrete samples from each reach and each zone (zones 2, 3A, 3B, and 4). Rely on statistical models to determine samples sizes (approx. N = 8).	Every 5 years and concurrent with water sampling years.	1976–1998	40 years	PCB congeners, mercury, DDE, lipids

Table 5-2 Proposed Long-term Monitoring Plan for the Lower Fox River and Green Bay (Continued)

RAO	Monitoring Element	Sample Type	Location [4, 5]	Frequency	Years with Historical Data	Expected Duration Over Time [2]	Analyses [3, 6]
Environment Health (RAO 3) (Continued)	Invertebrate tissue (benthos)	Whole body composites of zebra mussels. Fixed nearshore locations over time.	Collect samples from each reach near the dams (end of reach) and each Green Bay zone. When possible, co-locate near water sample locations (approx. N = 8 composites).	Every 5 years and concurrent with water sampling years.	1987/1988 Green Bay only	40 years	PCB congeners, mercury, DDE
	Bird tissue - piscivorous	Resident whole body common terns. Fixed locations over time.	Collect samples from Green Bay - zones 1, 2, 3A, 3B, and 4. Sample 2 to 3 nest sites (approx. N = 10 per nest site).	Every 5 years and concurrent with water sampling years	1986, 1996, 1997	40 years	PCB congeners, mercury, DDE, lipids
	Bird tissue-bald eagles	Collect eggs and blood plasma.	Collect from 2 sites along the LFR and 2 sites from Green Bay. If possible, three samples per site.	Every 5 years and concurrent with water sampling years.	Limited: 1985, 1987, 1990	40 years	PCB congeners, mercury, DDE
	Birds - reproductive assessment	Resident terns. Collect nest counts and egg counts per nest.	Collect samples from Green Bay - zones 1, 2, 3A, 3B, and 4.	Every 5 years concurrent with bird tissue sampling years	unknown	40 years	Compare to reference areas
	Birds - reproductive assessment for raptors	Resident bald eagles. Collect occupied nest counts, egg counts per nest, YOY counts per nest.	Collect from 2 sites along the LFR and 2 sites from Green Bay. If possible, three samples per site.	Every 5 years and concurrent with bird tissue sampling years.	unknown	40 years	Compare to reference areas
	Mammal reproductive assessment	Observational survey along shoreline of river and bay.	Collect data from multiple sites along river and bay in areas with suitable habitat.	Every other year for 10 years.	unknown	40 years	Compare to previous years

Table 5-2 Proposed Long-term Monitoring Plan for the Lower Fox River and Green Bay (Continued)

RAO	Monitoring Element	Sample Type	Location [4, 5]	Frequency	Years with Historical Data	Expected Duration Over Time [2]	Analyses [3, 6]
Contaminant Transport (RAO 4)	Surface sediment	0 to 10 cm discrete surface grabs at fixed stations over time.	Collect from 6 fixed locations per reach and per zone (Green Bay zones 2, 3A, 3B, and 4). Stations will be located in depositional areas.	Every 10 years and concurrent with water sampling years.	1987–1999	40 years	PCB congeners, mercury, DDE, grain size and TOC
	Bathymetry	Echo soundings.	Multiple transects per reach and zone and include nearshore areas.	Every 3 years for 10 years.	many	40 years	Compare to previous years
	Water column	Discussed under RAO 1.					
Releases During Remediation (RAO 5)	As appropriate [1]	Not included in the long-term monitoring plan.					

Notes:

[1] An adequate confimration/verification sampling program with physical, chemical, and biological elements will be in-place prior to initiation of the long-term program to verify implementation of an active remedy. Sediment, tissue, and water data will be collected during active remediation to supplement the baseline data set.
[2] Duration includes 10 years during before and during remediation for baseline, 10 years until angler fish consumption, and 20 years for general fish consumption.
[3] Use consistent sampling methods over time. For fish, sample same time of year. Include physical data about fish: size, length, weight, sex, and age of fish.
[4] The four reaches of the Lower Fox River include Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, and De Pere to Green Bay (also Zone 1). The four zones of Green Bay include 2, 3A, 3B, and 4.
[5] Most monitoring parameters will also include a background/reference station for comparison with Lower Fox River and Green Bay sampling station data.
[6] PCB congeners include Wisconsin State Laboratory PCB Congener List and coplanar dioxin-like PCB congeners.

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Attachment 1

Summary of Regional and National Monitoring Programs

Project Name: Disposal Area Monitoring System (DAMOS)

Location: New York, Connecticut, Rhode Island, Maine

Management Issues: Monitoring at open water disposal sites.

Water Body Type: Marine

Period of Performance: 1977 to Present

Background:
Dredged materials from numerous industrialized harbors in New England were placed in offshore subaqueous disposal sites between Long Island Sound and Maine. The contaminated material was subsequently capped with cleaner material. The New England district of the U.S. Army Corps of Engineers created the Disposal Area Monitoring System (DAMOS) in 1977. The DAMOS program was established to ensure disposal of dredged material had no adverse effect on the environment.

Project Goals and Objectives:
The DAMOS monitoring program was implemented to ensure the physical integrity and stability of disposal mounds, to measure the impacts to bottom organisms around the disposal mounds during placement and subsequent recolonization success, and to measure the effectiveness of capping in isolating disposed contaminated sediments (USACE, 1992).

Long-Term Monitoring:
Monitoring under the DAMOS program followed a tiered approach, under which techniques in the higher tiers were used only when monitoring results of lower tiers indicate the need for further monitoring. Although the schedule varied greatly depending on time and location, sampling generally occurred annually with additional sampling conducted after major storm events. Samples were routinely collected at reference sites to provide comparison with background results.

> *Physical:* High-resolution bathymetric surveys have been included in all monitoring surveys conducted under the DAMOS program. Additional physical monitoring included physical sediment description, grain size analysis, and sediment volume determinations made using diver surveys, and after 1982, the REMOTS® sediment-profiling camera.
>
> *Chemical:* Chemical monitoring was limited to routine analyses of surface sediments to assess contaminant levels (USACE, 1995). Sediments were collected using a 0.1-m^2 Smith-McIntyre mechanical grab sampler. Subsamples were collected with plastic core liners measuring approximately 6.5 cm in diameter by 10 cm in length. Occasionally, divers collected sediment samples for chemical analysis directly in plastic core liners.
>
> *Biological:* The biological component of the monitoring program has varied with respect to time and disposal site. Biological monitoring conducted under the DAMOS program included benthic infauna observations at all monitoring sites. Benthic infauna studies were conducted on surface grab samples obtained with a 0.1-m^2 Smith-McIntyre sampler. Samples were sieved through a 1.0-mm sieve and macrofauna were sorted, identified, and counted to measure community structure. Since 1982, the benthic community has been assessed using sediment profile imaging with the REMOTS® camera. In areas where monitoring demonstrated a decline in biological quality, the tiered approach triggered additional monitoring. Additional monitoring analyses

included measurements of bioaccumulation in caged mussels and resident worms (*Nephtys incisa*), and sediment amphipod toxicity tests.

Project Outcome:
Monitoring results obtained in the DAMOS program have not shown any evidence of physical or chemical breaching of capped areas. Physical data collection has shown that the sand caps are stable. Chemical data have shown the cap is effective in isolating contaminants, and biological measurements have demonstrated recolonization of the capped areas and the absence of toxicity.

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References:
USACE, 1995. Sediment Capping of Subaqueous Dredged Material Disposal Mounds: An Overview of the New England Experience, 1979-1993. U.S. Army Corps of Engineers, New England Division. Report No. SAIC-90/7573&C84. August.

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Project Name: Environmental Monitoring & Assessment Program (EMAP)

Location: National

Management Issues: Condition of ecological resources.

Water Body: Estuarine

Period of Performance: Ongoing from 1984 to Present

Background:
The Environmental Monitoring and Assessment Program (EMAP) is an EPA research program used to develop the tools necessary to monitor and assess the status and trends of national ecological resources. EMAP's goal is to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of ecological condition and forecasts of future risks to the sustainability of our natural resources. EMAP's research supports the National Environmental Monitoring Initiative of the Committee on Environment and Natural Resources (CENR).

Project Goals and Objectives:
EMAP objectives are to advance the science of ecological monitoring and ecological risk assessment, guide national monitoring with improved scientific understanding of ecosystem integrity and dynamics, and demonstrate the CENR framework through large regional projects. EMAP will develop and demonstrate indicators to monitor the condition of ecological resources, and investigate multi-tier designs that address the acquisition and analysis of multi-scale data including aggregation across tiers and natural resources (EPA, 2000).

Long-Term Monitoring:
EMAP's sampling scheme consists of systematic, random, and fixed location sampling elements. Large, continuously distributed estuaries are sampled using a randomly placed systematic grid, with grid points about 18 km apart. Large tidal rivers are sampled along systematically spaced lateral transects. Transects are located about 25 km apart. Two sampling points are located on each transect, one randomly selected, and one using scientific judgement to identify sampling locations that may be indicative of degraded conditions in the system. Small estuaries are sampled by partitioning them in groups of four, selecting one estuary randomly from each group of four, and sampling at two stations in each small estuary selected. EMAP operates on a 4-year sampling cycle, with one-fourth of the sites in a region sampled each year. Sampling is undertaken only during the months of July and August (EPA, 1995). Monitoring elements selected for a project are site-specific but likely include the following physical, chemical and biological parameters:

Physical: Monitoring data collected for physical parameters includes sediment grain size and water quality vertical profile data.

Chemical: Sediment samples are analyzed for chemical parameters of concern in a project area.

Biological: Biological monitoring is conducted on the benthic community, fish, invertebrates, and demersal trawl samples. Analyses include species abundance, community data, tissue chemistry, length data by taxa, and community abundance.

Project Outcome:
EMAP's Estuaries Group assessed the status and trends on the condition of the nation's estuaries extending from low to high tide elevations. In addition to coastal embayments, bays, inland waterways, and tidal rivers, the Estuaries Group also monitored coastal wetland areas and salt-water marshes. Monitoring and assessment activities were conducted jointly by the USEPA and the National Oceanic and Atmospheric Administration (NOAA). Monitoring results were not specified.

Project Contact:
None available

References:
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EPA, 1997. Environmental Monitoring and Assessment Program (EMAP) Research Strategy. U.S. Environmental Protection Agency, Office of Research and Development. EPA/620/R-98/001. October.

Project Name: Great Lakes National Program

Location: Chicago, Illinois

Management Issues: Restore and preserve ecological resources in the Great Lakes and protect human health in accordance with the Great Lakes Water Quality Agreement between U.S. and Canada.

Water Body Type: Lacustrine

Period of Performance: 1972 to Present

Background:
The Great Lakes National Program Office (GLNPO) was created in 1978 to coordinate the U.S. response to the Great Lakes Water Quality Agreement with Canada mandated by the Clean Water Act. The GLNPO, located in Chicago, Illinois, is made up of scientists, engineers, and other professionals. The GLNPO works with EPA, Environment Canada, Ontario Provincial government, International Joint Commission, and other agencies to achieve specific environmental goals through coordinated activities. Surveillance and monitoring began in 1972 under the Great Lakes Water Quality Agreement between the United States and Canada to identify problems and to measure progress in solving problems. A new Great Lakes Water Quality Agreement was signed in 1978, continuing the basic features of the previous agreement. Biannual surveillance and monitoring are continuing to the present.

Project Goals and Objectives:
The Great Lakes Water Quality Agreement with Canada, signed in 1972 established the environmental goals to restore the chemical, physical, and biological of the Great Lakes, achieve healthy plant, fish, and wildlife populations, and to protect human health. After assessing risks to the Great Lakes ecosystem the following objectives were established:

- Reduction of the level of toxic substances in the Great lakes and the surrounding habitat, with an emphasis on persistent toxic substances, so that all organisms are adequately protected and the substances are virtually eliminated from the Great Lakes Ecosystem.

- Protection and restoration of habitats vital for the support of healthy and diverse communities of plants, fish, and wildlife, with an emphasis on interjurisdictional fish and wildlife habitats, wetland habitats, and those habitats needed by threatened and endangered species.

- Protection of human and non-human health by restoring and maintaining stable, diverse, and self-sustaining populations of fish and other aquatic organisms, wildlife, and plants.

Long-Term Monitoring:
Surveys are completed biannually from the R/V Lake Guardian. Samples are taken from eight to 20 stations in each lake.

Physical: Standard sampling locations were tested for conductivity, temperature, and depth. In some locations additional visual surveys were conducted by divers, a remotely operated vehicle, or a submersible probe.

Chemical: Surface water samples were collected with vertical water samplers and a rosette water sampler and analyzed for chemical contaminants. Sediment samples were collected with a box corer, vibracore, or Mudpuppy. Contaminants of concern analyzed in water and sediment samples included mercury, PCBs, and pesticides.

Biological: Plankton and zooplankton samples were collected with plankton nets. Fish samples were collected to assess populations and contaminant concentrations. A number of fish species were collected including Coho salmon, bloater chub, and lake trout. A benthic invertebrate sampling program was initiated for Great Lakes in 1997. Sampling is conducted annually at a minimum of 45 stations.

Project Outcome:
Significant advances have been made to eliminate pollutant sources and contaminant concentrations in the Great Lakes since the Great Lakes Nation Program Office was established. The organization continues to coordinate efforts between numerous agencies and the public.

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References:
EPA, 2000a. Protecting the Great Lakes, A Joint Federal/State 5-Year Strategy (1992-1997). U.S. Environmental Protection Agency. April 1992 Draft. Website. http://www.epa.gov/glnpo/plans/5yrstrat.html.

EPA, 2000b. United States Great Lakes Program Report on the Great Lakes Water Quality Agreement. U.S. Environmental Protection Agency. Last Revised February 3, 1998. Website. http://www.epa.gov/glnpo/glwqa/usreport.

Sea Grant, 2000. Glossary of the Great Lakes. Last updated October 13, 1998. Website. http://www.d.umn.edu/seagr/pubs/GGL/G.html.

Project Name: National Status and Trends Program

Location: National

Management Issues: The program was established to measure the effect of human activities on coastal and estuarine waters.

Water Body Type: Estuarine and Marine

Period of Performance: National Benthic Surveillance Project from 1984 to present; Mussel Watch Project from 1986 to 1992

Background:
The National Status and Trends (NS&T) Program is administered by the National Oceanic and Atmospheric Administration (NOAA). The NS&T program was initiated in response to the need to gather information of the effect of human activities on environmental quality of coastal and estuarine areas. In October 1983, marine scientists from government, academia, and the private sector met to discuss the feasibility of a nationwide monitoring program. The workshop developed a list of contaminants of concern which have a demonstrated health risk, have been released into the environment in significant quantities, have long half-lives, and have a high potential for bioaccumulation. The NS&T sampling program was initiated in 1984 and continues to collect information from United States estuarine and coastal waters to date.

Project Goals and Objectives:
The NS&T program was developed to determine the status and trend of changes in the environmental quality of estuarine and coastal waters of the United States. In 1987, the program was expanded to measure the biological effects due to contaminant exposure (NOAA, 2000a).

Long-Term Monitoring:
Monitoring included in the NS&T program is divided into the National Benthic Surveillance Project (NBSP) and the Mussel Watch Project (MWP). The NBSP is responsible for quantification of contamination in fish tissue and sediment, and for developing and implementing new methods to define the biological significance of environmental contamination. The MWP monitors contaminant concentrations by quantifying chemicals in bivalve mollusks and sediments. These two subprograms are described below.

Physical: No physical monitoring parameters were included in these programs.

Chemical: Sediment samples were collected for both the NBSP and the MWP. Sediment samples were collected concurrently with fish samples at each NBSP site. Samples of the top 3 cm of sediment were collected using a specially constructed box corer or a Smith-MacIntyre grab sampler. At MWP sites, sediment samples of the top 1 cm of sediment were collected from three locations and composited. Samples were collected using a Kynar-coated Young-modified Van Veen grab sampler, stainless steel box-cores, or Kynar-coated scoops. Sediment samples for both programs were analyzed for organic and metal contaminants. Organic contaminants included PAHs, PCBs, and chlorinated pesticides.

Biological: Fish tissue samples were collected for the NBSP from 1984 to 1993 (unknown if fish samples are still being collected). Fish were usually collected with otter trawls, although hook and line or gill nets were occasionally used. Samples were collected from three stations at each

2-km diameter NBSP site. A number of different benthic fish were collected including flatfish at least 15 cm in length and roundfishes at least 12.5 cm in length. Tissues analyzed in the NBSP program included liver, muscle, and stomach contents. Liver tissue was the most commonly measured matrix in fish samples. Analyses included metals, histopathology, organics, aryl hydrocarbon hydroxylase, and xenobiotic-DNA adducts. Organic analyses included butyltins, PCBs, DDT and metabolites, and other chlorinated pesticides. PAHs were not analyzed in fish liver tissue because they are readily metabolized. Muscle analytical methods were similar to liver tissue. Stomach contents were analyzed for organic compounds, metals, and food item taxonomy (NOAA, 2000b).

Bivalve mollusks were collected on an annual basis from 1986 to 1992 for the MWP. After 1992, samples were collected biennially. Samples were collected from 150 sites in 1986 and over 250 sites in 1992. Samples were collected between mid-November and the end of March, and within three weeks of the date the site was first sampled to avoid effects of spawning on chemical concentrations. Several species were collected including blue mussels (*Mytilus edulis*) from the U.S. North Atlantic, blue mussels (*Mytilis sp.*) and California mussels (*M. californianus*) from the Pacific coast, American oysters (*Crassostrea virginica*) from the South Atlantic and the Gulf of Mexico, smooth-edge jewelbox (*Chama sinuosa*) from the Florida Keys, Caribbean oyster (*C. rhizophorae*) from Puerto Rico, tropical oysters (*Ostrea sandvicensis*) from Hawaii, and zebra mussels (*Dreissena polymorpha* and *D. bugensis*) from the Great Lakes (NOAA, 2000c). Bivalves were collected at intertidal sites by hand and at subtidal sites with an oyster dredge or oyster tongs. Zebra mussels were collected by snorkeling or with an epibenthic dredge. Composite samples of 30 mussels or 20 oysters (or approximately 200 zebra mussels) were analyzed for organic and metal contaminants. Organic contaminants included PAHs, PCBs, and chlorinated pesticides (NOAA, 1993).

Project Outcome:
The program established an extensive database with the attempt to evaluate the success of recent attempts to improve environmental quality. While the project maintained the same core of station sites and analytical parameters to establish long-term trends, the program evolved to included better analytical methods and new information.

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References:
NOAA, 2000a. National Status and Trends Benthic Surveillance Project. Website. http://ccmaserver.nos.noaa.gov/NSandT/NsandTmethods.html.

NOAA, 2000b. National Status and Trends Mussel Watch Project. Website. http://ccmaserver.nos.noaa.gov/NSandT/NsandTmethods.html.

NOAA, 2000c. National Status and Trends Program. Website. http://ccmaserver.nos.noaa.gov/NSandT/NsandTmethods.html.

NOAA, 1993. Sampling and Analytical Methods of the National Status and Trends Program National Benthic Surveillance and Mussel Watch Projects, 1984-1992. Volume I. National Oceanic and Atmospheric Administration. Technical Memorandum NOS ORCA 71. July.

Project Name: Puget Sound Ambient Monitoring Program (PSAMP)

Location: Puget Sound, Washington

Management Issues: Measurement of effects of human activities on environmental conditions.

Water Body Type: Estuarine and Marine

Period of Performance: 1989 to Present

Background:
This program is managed by the Washington State Department of Ecology and often coordinates efforts with NOAA's NS&T program (NOAA and Ecology, 1999). An interdisciplinary group of sediment and water quality professionals was appointed by the Puget Sound Water Quality Authority to develop a comprehensive monitoring program for Puget Sound in 1986. The group designed the Puget Sound Ambient Monitoring Program (PSAMP) to provide long-term monitoring of water quality, sediment quality, biological resources, nearshore habitats, and rivers in the Puget Sound Basin (Llanso et. al, 1998a). Two subprograms of PSAMP include the Marine Sediment Monitoring Program (MSMP) and the Marine Water Column Ambient Monitoring Program. The Marine Sediment Monitoring Program (MSMP) operated under PSAMP from 1989 until 1995. The Marine Water Column Ambient Monitoring Program was initiated in 1967 and joined PSAMP in 1989. Details of the subprograms are discussed below.

Project Goals and Objectives:
The objectives of the MSMP were to collect data on Puget Sound sediments and macro-invertebrate communities in contaminated and uncontaminated areas and to evaluate the condition of Puget Sound benthic communities in relation to contaminant concentrations. The objectives of Marine Water Column Ambient Monitoring Program were to collect data for the maintenance of regulatory listings of various water bodies throughout the state and to implement marine water quality management activities based on water quality data (Ecology, 2000).

Long-Term Monitoring:
Sediment samples were collected from 76 stations throughout Puget Sound, Hood Canal, and the Strait of Georgia from 1989 to 1995. Thirty-four stations were sampled annually. Stations were analyzed using the sediment quality triad approach which included sediment chemistry, sediment toxicity, and benthic community structure assessments. The remaining 42 stations were sampled on a 3-year rotational basis in north, central, and south Puget Sound. Five replicate sediment samples were collected at each station using a double 0.1-m^2 stainless steel Van Veen grab sampler. The top 2 cm were composited and analyzed for physical, chemical, and biological parameters (Llanso et. al, 1998b).

Water column monitoring in 1996 consisted of 16 annually sampled stations and 13 stations sampled on a 3-year rotational basis. In 1997, water column monitoring took place at 19 stations annually and six stations on a rotational basis. The numbers of sampling stations in other years were not available. Water samples were collected at depths of 0.5, 10, and 30 meters with a 1.2-liter Niskin® bottle (Newton et. al, 1998).

> *Physical:* Sediment samples were inspected for visual and olfactory character and analyzed for particle size. A Secchi disk was used to indicate water clarity at water column sampling stations.

Chemical: Sediment samples were analyzed for metals, volatile and semivolatile organic compounds, chlorinated pesticides, PCBs, total organic carbon (TOC), and total sulfides. Water column samples were analyzed for dissolved nutrients (ammonium-N, nitrate + nitrite-N, and orthophosphate-P), pigments (chlorophyll-a and phaeopigment), dissolved oxygen, and fecal coliform bacteria.

Biological: Sediment sample bioassays were conducted on the amphipod, *Rhepoxynius abronius*, as a measure of acute sediment toxicity. Bioassays were conducted on sediment from each sampling location, although no bioassays were conducted in 1994 or 1995. Benthic infauna enumeration was completed at all sediment sampling locations annually from 1989 through 1995 (Llanso et al., 1998a and 1998b).

Project Outcome:
Water column monitoring measured diverse conditions in Puget Sound. Open basins generally had good water quality, however, individual locations had reduced water quality. Estuarine water quality was good with the exception of chronic fecal coliform bacteria. Sediment monitoring succeeded in measuring the type of contamination in Puget Sound locations, although little is known of the extent of contamination. Overall the extent of contamination was low, but elevated contaminant concentrations were present in localized areas, particularly in urban bays.

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References:

Ecology, 2000. Washington State Department of Ecology, Marine Sediment Monitoring. Last updated September 22, 1999. Website. http://www.wa.gov/ecology/eils/mar_sed/msm_intr.html.

Llanso, R. J., S. Aasen, and K. Welch, 1998a. Marine Sediment Monitoring Program, I. Chemistry and Toxicity Testing, 1989-1995. Washington State Department of Ecology. Publication No. 98-323. August.

Llanso, R. J., S. Aasen, and K. Welch, 1998b. Marine Sediment Monitoring Program, II. Distribution and Structure of Benthic Communities in Puget Sound, 1989-1993. Washington State Department of Ecology. Publication No. 98-328. September.

Newton, J. A., Albertson, S. L., K. Nakata, and C. Clishe, 1998. Washington State Marine Water Quality in 1996 and 1997. Washington State Department of Ecology. Publication No. 98-338. December.

NOAA and Ecology, 1999. Sediment Quality in Puget Sound Year 1 – Northern Puget Sound. Puget Sound Ambient Monitoring Program and NOAA NS&T. Publication No. 99-347. December.

Contaminated Sediment Monitoring Programs – Review of Monitoring Methods

Project Name: San Francisco Estuary Project/National Estuary Program

Location: San Francisco, California

Management Issues: Toxic compounds in sediment, habitat loss and alteration, species loss and decline, fisheries loss and decline, introduced and pest species, and problems with the quantity of freshwater inflow.

Water Body Type: Marine/Estuarine

Period of Performance: 1993 to Present

Background:
The San Francisco Estuary Project is part of the National Estuary Program which was established in 1987 by amendments to the Clean Water Act to identify, restore, and protect nationally significant estuaries of the United States. The NEP targets a broad range of issues and engages local communities in the process. The program focuses on improving water quality in an estuary through maintaining the integrity of the whole system including chemical, physical, and biological properties, as well as its economic, recreational, and aesthetic values.

Project Goals and Objectives:
The National Estuary Program (NEP) is designed to encourage local communities to take responsibility for managing their own estuaries. Each NEP is made up of representatives from federal, state and local government agencies responsible for managing the estuary's resources, as well as members of the community—citizens, business leaders, educators, and researchers. These stakeholders work together to identify problems in the estuary, develop specific actions to address those problems, and create and implement a formal management plan to restore and protect the estuary.

The Comprehensive Conservation Management Plan (CCMP) presents a blueprint of 145 specific actions to restore and maintain the chemical, physical and biological integrity of San Francisco Bay and Delta. It seeks to achieve high standards of water quality; to maintain an appropriate indigenous population of fish, shellfish and wildlife; to support recreational activities; and to protect the beneficial uses of the Estuary.

To assist in coordinating research and monitoring programs, the San Francisco Estuary Project has fostered the development of a Regiona1 Monitoring Strategy (Monitoring Strategy). Project staff have worked with representatives of government agencies and scientific institutions to establish the Monitoring Strategy, which fulfills an action recommended in the CCMP's Research and Monitoring Program. The primary purposes of the Regional Monitoring Strategy are: 1) to provide information to assess the effectiveness of management actions that have been taken, 2) to improve conditions in the Estuary to protect its resources, 3) to evaluate the ecological "health" of the Estuary, and 4) to enhance scientific understanding of the ecosystem (San Francisco Estuary Project, 1998).

Long-Term Monitoring:
The San Francisco Estuary Institute (SFEI) serves as the coordinating entity for the Regional Monitoring Strategy. Monitoring is performed annually by the SFEI under the Regional Monitoring Program (RMP). Monitoring began in 1993. In an effort to capture seasonal variability, samples are collected three times per year: during the rainy season (March-April), during a period of declining delta outflow (May-June), and during the dry season (August-September). Two dozen sampling stations are located throughout the Estuary and its major tributaries. Most station locations are chosen as far as possible from the influence of local contaminant sources to best represent "background" contaminant concentrations. Other stations

are close to wastewater outfalls or creek mouths for comparison purposes. To ensure that the data collected by different groups participating in the monitoring program are directly comparable, protocols that included performance-based and standardized sampling, analytical, and QA/QC protocols are employed (San Francisco Estuary Institute, 2000).

Physical: Sediment is analyzed for physical characteristics such as particle size.

Chemical: Chemical monitoring is conducted both for water and sediment. Conventional water quality data are collected including salinity, dissolved oxygen, and temperature. Water is also analyzed for chemical contaminants such as metals, pesticides, and other synthetic hydrocarbons.

Biological: The biological monitoring program includes sediment toxicity, benthic infauna, water column toxicity, and contaminant bioaccumulation. Sediment samples consist of the top 5 cm of grab samples. Benthic infauna is also measured from grab samples and sediment toxicity is evaluated through the effect of the sediment on laboratory organisms.

Water column toxicity is evaluated using a 48-hour bivalve embryo development test and a 7-day growth test using the estuarine mysid *Mysidopsis bahia*. The RMP uses two sediment bioassays: a 10-day acute mortality test using the estuarine amphipod *Eohaustorius estuarius* exposed to whole sediment, and a sediment elutriate test where larval bivalves are exposed to the material dissolved from whole sediment in a water extract. Water column samples are collected approximately 1 meter below the water surface.

Contaminant bioaccumulation is evaluated in transplanted shellfish. For the bivalve bioaccumulation sampling, bivalves are collected from uncontaminated sites and transplanted to 15 stations in the estuary during the wet season (February through May) and the dry season (June through September). Contaminant concentrations in the animals' tissues and the animals' biological condition are measured before deployment and at the end of the 90- to 100-day deployment period. Since the RMP sites encompass a range of salinities, three species of bivalves are used, according to the expected salinities in each area and the known tolerances of the organisms. Organisms used in the bioaccumulation studies are mussel (*Mytilus californianus*) with 49- to 81-mm shell length, oyster (*Crassostrea gigas*) with 71- to 149-mm shell length, and clams (*Corbicula fluminea*) with 25- to 36-mm shell length.

Project Outcome:
None specified. Results are ongoing.

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References:
San Francisco Estuary Project, 1998. Last updated July 1, 1998. Website. http://www.abag.ca.gov/bayarea/sfep/.

San Francisco Estuary Institute, 2000. Last updated March 18, 2000. Website. http://www.sfei.org.

Attachment 2

Draft Report on the Lake Michigan Tributary Monitoring Project

Assessment of the Lake Michigan Monitoring Inventory

A Report on the Lake Michigan Tributary Monitoring Project

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Executive Summary

Introduction

Through a cooperative agreement, the Great Lakes Commission worked with the U.S. Environmental Protection Agency (U.S. EPA) Region 5, and its partners in the Lake Michigan Lakewide Management Plan (LaMP) process, to assess existing monitoring efforts in the Lake Michigan basin and subwatersheds, including the ten Lake Michigan Areas of Concern (AOC) and four other tributary watersheds. This report is one of the outcomes of the project, and includes a comprehensive review of monitoring programs at the federal, state and local levels for the targeted watersheds; an analysis of gaps, inconsistencies and unmet needs; an assessment of the adequacy of existing efforts to support critical ecosystem indicators; and recommendations for addressing major monitoring needs, particularly those considered most important for lakewide management decision making. The report has also been used to inform members of the Lake Michigan Forum, local public advisory councils (PACs), and other stakeholders about identifying current, local monitoring efforts and establishing community-based monitoring programs.

Monitoring was broadly defined for this project to include not only traditional water quality parameters, but also habitat, wildlife, land use, nonpoint source pollution and other measures of ecosystem health. It is intended that the report and future project outcomes will provide U.S. EPA, the PACs and other stakeholders with important tools for developing their Remedial Action Plans (RAPs) and will enable them to engage their community in a valuable dialogue regarding the status of knowledge on their local watershed. Working closely with the states and tribal authorities, they will benefit from the exchange of information and the opportunity to enhance local participation in state-sponsored monitoring programs.

Project participants were responsible for conducting this assessment at the local level in their watersheds. This consisted primarily of implementing a survey of potential local monitoring organizations and conducting follow-up interviews. The Great Lakes Commission, in collaboration with the U.S. EPA and other agencies, assessed monitoring being conducted by state and federal agencies. The Commission then compiled the results of this collaborative effort into an inventory database, which was the basis for this report. Please see the methodology chapter for a background on project participants, as well as methods used to gain information to build the inventory.

Results

The results from an analysis of the monitoring inventory are organized along several lines. First, each tributary watershed is reviewed separately, with an additional chapter on open lake and basinwide monitoring. Watersheds for the following tributaries are covered in this report:

Grand Traverse Bay
White Lake
Muskegon Lake
Grand River
Kalamazoo River
St. Joseph River
Grand Calumet River
Waukegan Harbor
Milwaukee River and Estuary
Sheboygan River
Fox-Wolf River Basin
Door County
Menominee River
Manistique River

Within each of these chapters, findings from the inventory are presented in the following nine categories:

- LaMP pollutants
- Nutrients and bacteria
- Meteorological and flow monitoring
- Sediments
- Fish contaminants, fish health, and aquatic nuisance species
- Benthos monitoring
- Air monitoring
- Wildlife monitoring
- Land use

In addition to discussing findings for each of the watersheds, monitoring locations (where available) are also displayed for each watershed. The combination of database analysis and geographical analysis was designed to present the most complete assessment of monitoring within each watershed.

Following the open lake chapter, a more general analysis of monitoring coverage is presented in chapter 18, Overall Discussion. In this section, the monitoring infrastructure was analyzed for its ability to provide sufficient data for assessing the 70 Lake Michigan LaMP indicators. A qualitative rating is given to each LaMP indicator, based on the availability and specificity of monitoring related to the indicator.

Findings and Recommendations

The final section of this report centers on general issues that were uncovered throughout the course of research. There are three key areas under which the monitoring inventory provided valuable information and recommendations for improving overall monitoring in the Lake Michigan basin. These include data gaps and unmet needs; underutilized resources; and monitoring coordination and information sharing. Findings and recommendations within these areas are summarized below. More detail can be found in the last chapter of the report. For reference purposes, sections are labeled with letters and findings and recommendations are numbered.

A. Data Gaps and Unmet Needs

This report, and the inventory on which it is based, represent the first effort to account for the range of environmental monitoring in the Lake Michigan basin. The inventory represents the initial approach toward achieving this ambitious goal. It is a framework on which a more complete inventory will eventually be built.

(1) Finding: There are several gaps in the inventory that are listed below and throughout the report. While some of these gaps are areas that have not been well covered in the inventory, others may represent gaps in the monitoring coverage. At this point, it is difficult to tell which are gaps in the monitoring inventory and which are actual monitoring gaps. Further improvement of the inventory database is needed to better clarify this distinction.

(1.1) Recommendation: *Continue to update the inventory and expand data collection to include all tributaries.*

(2) Finding: There are several key monitoring areas where little information was received, but where more monitoring is believed to exist. These areas include monitoring for *E. coli*, fish population characteristics, aquatic nuisance species, benthic organisms, wildlife, and habitat.

(2.1) Recommendation: *Establish better lines of communication with state Departments of Natural Resources (DNR), U. S. Fsih and Wildlife Service (USFWS), U. S. Forestry Service (USFS), and U. S. Department of Agriculture (USDA).*

(2.2) Recommendation: *Better integrate habitat and wildlife monitoring with traditional water quality monitoring.*

(3) Finding: Another result of this initial approach to the monitoring inventory for the Lake Michigan basin was that much of the information included only general information about the geographic location of monitoring sites. Many organizations reported monitoring for parameters across a broad geographic area but did not include specific site references. Locational information is critical if the inventory is to be brought online in a geographically-searchable format.

(3.1) Recommendation: *Improve information on the geographic location of monitoring sites.*

(4) Finding: A further gap in the monitoring information obtained for this report, was the lack of complete and continuing coverage of Lake Michigan Mass Balance data. Data obtained for this report on the Lake Michigan Mass Balance Project was limited by the timing of the release of data to the public. However, information in the inventory database will be improved when the project is finalized. Additionally, the value of coordinated sampling data (as collected in the Mass Balance project) would be greatly enhanced by a repeat of the sampling event ten years following completion of the original sampling.

(4.1) Recommendation: *Initiate planning for a coordinated sampling event for ten years following the initial Mass Balance project, and share data and modeling results with the public in a timely fashion through numerous outlets.*

(5) Finding: This initial project specifically avoided attempting to collect information about university monitoring projects. However, some academic institutions conduct a number of important ongoing, long-term projects, and information on these projects should be included in the inventory. Other programs catalog the university work they fund. Closer ties need to be established with these programs and such efforts need to be expanded throughout the basin.

(5.1) Recommendation: *Include academic research and data collection efforts in future updates to the monitoring inventory*.

(6) Finding: While a number of LaMP pollutants, such as mercury and copper, are monitored extensively across the basin, it has been difficult to find monitoring information on some of the other pollutants. These under-monitored pollutants include all the emerging LaMP pollutants, along with DDT, HCBs, toxaphene, and PAHs.

(6.1) Recommendation: *Further examine the monitoring coverage of specific LaMP critical pollutants and emerging pollutants.*

B. Underutilized Resources

Along with the gaps in monitoring coverage identified in this project, some resources in the basin were also discovered that do not appear to be fully utilized. Monitoring is an area of environmental management that has often been underfunded in the past. Therefore, in order to achieve the most complete monitoring coverage possible, all available resources must work in concert.

(1) Finding: One of these underutilized resources is volunteer groups. Most of the volunteer groups currently engage in some form of monitoring, but often their efforts are not incorporated into state or regional monitoring plans, and the information collected is only reported internally or locally.

(1.1) Recommendation: *Take better advantage of relatively untapped volunteer monitoring resources.*

(2) Finding: Another group that is underutilized is local agencies. Examples of such agencies are health departments, conservation districts and planning agencies. In many cases, these agencies are already engaged in monitoring to serve their local needs.

(2.1) Recommendation: *Take better advantage of local agencies such as health departments, conservation districts and planning agencies.*

(3) Finding: To best capitalize on these underutilized resources, it is important that these local groups (both volunteer groups and local agencies) be linked into basinwide efforts, but at the same time retain their local focus and discretion.

(3.1) Recommendation: *Establish a better framework for bottom-up monitoring program linkages.*

(4) Finding: Part of the difficulty in using data collected at the local level is that there are few standards at the basinwide level to integrate data. The local focus of the data collection effort often will leave the data incompatible with other data from neighboring localities.

(4.1) Recommendation: *Standardize data collection and reporting*.

C. Monitoring Coordination and Information Sharing

The final issue area does not involve direct monitoring, but responds to the need to coordinate monitoring efforts. There are a wide array of organizations involved in monitoring at the federal, state and local levels. However, no single organization is responsible for planning, coordinating, or disseminating monitoring efforts for the entire Lake Michigan basin.

(1) Finding: A major coordination problem is the lack of a central source for monitoring information. The inventory that this report evaluates is the first step toward creating such a central source. However, this one-time inventory is currently not universally accessible and may quickly become dated if the database is not continually updated by monitoring organizations in the basin.

(1.1) Recommendation: *Encourage state, federal, tribal, and local agencies to report monitoring coverage and results to a meta-database with universal access.*

(1.2) Recommendation: *Develop an online database of monitoring information that is geographically-based, and content-searchable.*

(2) Finding: In general, organizations make most, if not all, decisions about their monitoring programs based on goals for their local coverage areas. Rarely does this area cover the entire Lake Michigan basin.

(2.1) Recommendation: *Develop and coordinate the implementation of comparable methods to collect indicator data in a coordinated network.*

Acknowledgments

The primary authors of this report were Ric Lawson of the Great Lakes Commission, and the Lake Michigan Tributary Monitoring Project participants from the 14 participating tributary watersheds around the Lake Michigan basin. Mr. Lawson compiled state and federal monitoring information; designed and analyzed the monitoring inventory survey and database; integrated all other information into this final report; and provided day-to-day project management. The project participants collected information on local monitoring programs in their watersheds; compiled this information for population of the inventory database; reported on their findings (much of which is included directly in this report); and provided review comments to Mr. Lawson. These project participants, and their respective watersheds, are as follows:

Chris Wright — Grand Traverse Bay
Susan Russell — Grand Traverse Bay
Kathy Evans — White Lake and Muskegon Lake
Dr. Janet Vail — Grand River
Melissa Welsh — Grand River
Bruce Merchant — Kalamazoo River
Andrew Laucher — Kalamazoo River
Al Smith — St. Joseph River
John Wuepper — St. Joseph River
Kathy Luther — Grand Calumet River
Dr. Greg Olyphant — Grand Calumet River
Susie Scheiber — Waukegan Harbor
Paul Geiselhart — Waukegan Harbor
Dr. Vicky Harris — Milwaukee, Sheboygan, and Menominee Rivers
Nate Hawley — Milwaukee, Sheboygan, and Menominee Rivers
Bruce Johnson — Fox-Wolf River Basin
Jim Pinkham — Fox-Wolf River Basin
Roy Aiken — Door County
Jim Anderson — Manistique River

Contact information for these individuals is included in Appendix B.

In addition to the authors, several individuals made important contributions to the development of the inventory and this report. Judy Beck, Lake Michigan Team Manager with U.S. EPA, Region 5, served as the technical contact. Through the U.S. EPA she provided funding for the project, as well as project guidance, federal contacts, and overall support of the project through the LaMP process. Matt Doss, Program Manager with the Great Lakes Commission, provided project leadership, oversight, administration, and extensive editorial and task support for all aspects of the project. Dr. Michael Donahue and Tom Crane with the Great Lakes Commission provided guidance and important contact information.

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1. Introduction and Background

Lake Michigan Background

Lake Michigan is the second largest Great Lake, by volume. The lake is 307 miles long and 118 miles wide, with an average depth of 279 feet and a maximum depth of 925 feet. The Lake Michigan drainage basin covers more than 45,000 square miles. The shoreline of the lake stretches 1,660 miles.

Lake Michigan flows into Lake Huron through the Straits of Mackinac. The flow rate into Lake Huron allows Lake Michigan to be recharged once every 100 years, which is considered a relatively slow recharge rate. The lake supports a unique ecology, with colder forested regions dominating the northern half of the basin, and more temperate, fertile regions in the southern section.

Lake Michigan is located entirely in the United States, which made it uniquely situated for this project. Four states border the lake – predominately Michigan to the east and north, and Wisconsin on the western shore. Indiana and Illinois make up the southern shore of the lake, and while a small proportion of the basin area exists in these states, these areas contain significant natural areas, and high population and pollution sources.

The Lake Michigan basin consists of a variety of land uses. About 44 percent of the land in the basin is taken up in agricultural production. Roughly 41 percent exists as managed or unmanaged forest land. Nine percent of the remaining land is divided up into residential units, with a variety of uses making up the remaining 6 percent of the basin.

Monitoring Relevance to the Lake Michigan LaMP

Pursuant to the 1987 protocol to the Great Lakes Water Quality Agreement (GLWQA), Lakewide Management Plans (LaMP) have been developed for four of the five Great Lakes. The Lake Michigan LaMP effort was led by the U.S. Environmental Protection Agency (U.S. EPA), Region 5, in cooperation with its partners in the states of Michigan, Indiana, Illinois and Wisconsin, the public and other federal and tribal agencies. Additionally, Remedial Action Plans (RAPs) are being prepared and updated for ten Lake Michigan tributaries designated as Areas of Concern by the parties to the GLWQA.

According to the 1987 protocol, "LaMPs shall embody a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses in ... open lake waters." The LaMP process involves setting goals to reduce toxics, improve habitat, and restore beneficial uses to the environment in the Lake Michigan basin. The RAPs follow a similar approach in specific geographic areas where significant pollution problems have impaired beneficial uses of the water body.

An additional feature of the LaMPs and RAPs is a strong emphasis on public consultation and local involvement. For the Lake Michigan LaMP, this is achieved through the Lake Michigan Forum, a broad-based stakeholder group with members from tribes, industry, environmental groups, local government agencies, community organizations, academia, recreational organizations, and the ten Lake Michigan AOCs. Public advisory councils (PACs) are the primary vehicle for facilitating public involvement in the AOCs. The PACs include broad representation from the AOC community and guide the RAP process at the local level.

While the original draft Lake Michigan LaMP focused strongly on toxic pollutants, the participating agencies and stakeholders recognized that other stressors contribute to impairments of the lake and the tributaries that feed into it. In response, the latest version of the LaMP expanded its scope to address a broader array of management issues, including loss of habitat and biodiversity and introduction of damaging exotic species. The year 2000 draft of the LaMP includes the results of a number of studies and monitoring efforts to determine the fate of pollutants entering the Lake, and how they move through air or water or sediments into the food chain.

A critical component of this broader approach will be a monitoring regime that is coordinated from one jurisdiction to another and sufficiently comprehensive to support the ecosystem indicators which inform management decisions. The Lake Michigan Mass Balance Study will provide important data on the amount of several critical pollutants entering the lake, their movement and how they are made available to fish and plant life. An outstanding need remains, however, to assess the status and scope of monitoring being conducted at the state and local levels on major tributaries to Lake Michigan; to develop a plan for coordinating and enhancing these efforts; and to address gaps and unmet needs in the collective monitoring and reporting regime that hamper decision making at all levels.

Project Goals

Through a cooperative agreement, the Great Lakes Commission worked with U.S. EPA Region 5, and its partners in the Lake Michigan LaMP process, to assess existing monitoring efforts in Lake Michigan basin and subwatersheds, including the ten AOCs and four other tributary watersheds. This report is one of the outcomes of the project. The report includes a comprehensive review of monitoring programs at the federal, state and local levels for the targeted watersheds; an analysis of gaps, inconsistencies and unmet needs; an assessment of the adequacy of existing efforts to support critical ecosystem indicators; and a plan for addressing major monitoring needs, particularly those considered most important for lakewide management decision making. The report has also been used in training members of the Lake Michigan Forum, PACs, and other stakeholders on determining current, local monitoring efforts and establishing community-based monitoring programs.

The project and report are consistent with the ecosystem approach of the LaMPs and RAPs as well as their emphasis on community involvement and participation. Monitoring has been viewed in the broadest sense, including not only traditional water quality parameters, but also habitat, wildlife, land use, nonpoint source pollution and other measures of ecosystem health. It is intended that the report and future project outcomes will provide the PACs and other stakeholders with important tools for developing their RAPs and will enable them to engage their community in a valuable dialogue regarding the status of knowledge on their local watershed.

Scope of the Assessment Effort

This report assesses monitoring efforts in the broadest sense, including not only traditional water quality parameters, but also habitat, wildlife, land use, nonpoint source pollution and other measures of ecosystem health. Project participants were responsible for conducting this assessment at the local level in their watersheds. There were fourteen major Lake Michigan tributaries selected for local analysis. The watersheds impacting these tributaries were selected as the base unit of analysis. These watersheds are illustrated in Figure 1. The Great Lakes Commission, in collaboration U.S. EPA and other agencies, assessed monitoring being conducted by state and federal agencies. Please see the methodology chapter for a background on project participants, as well as methods used to gain information to build the inventory.

Figure 1. Watersheds included in the Lake Michigan Monitoring Inventory.

Report Framework

This report is structured along the lines of a typical research report. This introduction is followed by a discussion of the methodologies used to collect the information in the inventory and this subsequent report. The methodology is followed by a series of chapters that present the project findings and inventory content. Summaries of inventory results from each of the fourteen tributaries included in this project are presented in the following categories:

- *LaMP pollutants:* This category includes substances classified as water quality pollutants at three levels. Critical pollutants are those that have been found to impair beneficial uses of the lake and its tributaries. Included in this category are polychlorinated biphenyls (PCB), dieldrin, chlordane, dichlorodiphenyltrichloroethane (DDT) and metabolites, mercury, and dioxins and furans. Pollutants of Concern are those toxic substances that are associated with local or regional use impairments. These include arsenic, cadmium, chromium, copper, cyanide, lead, zinc, hexachlorobenzene (HCB), toxaphene, and polynuclear aromatic hydrocarbons (PAH). Finally, Emerging Pollutants include those toxic substances that have characteristics that indicate a potential to affect the physical or biological integrity of Lake Michigan. These include atrazine, selenium, and PCB substitute compounds.[1]

- *Nutrients and bacteria:* Nutrients, when present in high levels, can impair water bodies by encouraging the overproduction of algae and other plant life, leading to low oxygen levels and ultimately eutrophication. Several organisms which proliferate in high nutrient conditions include *E. coli* and coliform forms of bacteria. These bacteria can locally impair beneficial uses of water bodies.
- *Meteorological and flow monitoring:* Meteorological and flow monitoring represent two types of physical parameters that can be measured for water bodies. Meteorology (mostly relating to precipitation) and flow data help researchers develop water quality models, which have many uses, including source determination, Total Maximum Daily Load (TMDL) development, and other types of predictive modeling, to name just a few.
- *Sediments:* Contamination of bottom sediments is a common source of water quality impairment in AOCs in the Lake Michigan basin. Monitoring these sediments is important for determining the overall quality of a waterbody and its adjoining ecosystems.
- *Fish contaminants, fish health, and aquatic nuisance species:* Many species of fish in the basin take up chemical pollutants through the food web. Often, the effect is a bioaccumulation or concentration of pollutants within the fish tissue. This presents a significant health hazard to humans who consume this fish. Also, the health of fish populations in the lake and tributaries serves to indicate the health of the ecosystem to some degree. Nonindigenous Aquatic nuisance species can affect native aquatic species in a variety of ways. Monitoring of all these aspects of fish populations is important for tracking the health of life in the lake.
- *Benthos monitoring:* Similar to fish, there are a wide number of other organisms that exist deep within lakes and streams within the Lake Michigan basin. Many of these organisms are very sensitive to pollution and other aspects of a healthy aquatic system. Monitoring for the health and diversity of these species helps to determine the overall health of the aquatic ecosystem.
- *Air monitoring:* While monitoring the content of the air is an important task to determine intrinsic air quality, it is also important for tracking potential sources of water quality impairment. Much research is ongoing in the basin to determine how pollutants can be passed through the air to water bodies through air deposition.
- *Wildlife monitoring:* Any effort to track the health and quality of ecosystems must include some measure of the diversity and health of wildlife populations. Several types of public and private organizations are monitoring a variety of wildlife populations.
- *Land use:* One of the measures of human impact on the natural world is tracking the development of land. Changing the use of land from a naturally-controlled environment to agricultural production or urban or suburban habitation can have a wide range of impacts on the surrounding ecosystems. It is important to track these changes, along with measures of ecosystem health, to help determine the overall impacts from changes in land use.

In addition, each chapter begins with background about the watershed or region of focus, and ends with a local assessment of monitoring efforts. Both of these sections were written directly by the local project participants. Actual survey results will be made available for public use via a geographically-searchable Internet database, which is currently under development.

The tributary chapters are followed by a chapter assessing the monitoring coverage of the open lake and a discussion of state and federal monitoring programs which have a multiple watershed focus. This chapter is followed by a general discussion of the monitoring coverage in the Lake Michigan basin, focusing on gaps

[1]Definitions for LaMP pollutants were excerpted from the *Lake Michigan Lakewide Management Plan (LaMP 2000)*; U.S. EPA, 2000.

and unmet needs. The final chapter contains recommendations from the project participants, in consultation with numerous monitoring stakeholders, such as members of the Lake Michigan Monitoring Coordination Council.

2. Methodology

Attempting to take an inventory of all ecological monitoring efforts in a basin as wide in area as the Lake Michigan basin is a mammoth undertaking. Thousands of separate efforts may be ongoing, and few people outside project participants may be aware of many of them. Striving to become aware of all of these efforts is high goal — a goal that one cannot expect to achieve on the first attempt. We view the products of Lake Michigan Tributary Monitoring Project as comprising a foundation of a monitoring inventory. Over time, if the foundation is strong enough and enough people become aware of it, the inventory can be built upon so that it will eventually become complete. We envision the inventory as a dynamic product that should constantly be updated to reflect new discoveries and changes in monitoring efforts.

In this vein, the methods used to collect information and develop the inventory consisted of the following general elements:

- A two-tiered survey of potential monitoring organizations;
- Review and collection of supplemental or specific geographic monitoring information; and
- Development of an organizing framework for the inventory.

Monitoring Inventory Survey

A short survey (25 questions, 2 pages) was developed to solicit information about possible monitoring projects in the basin (See Appendix C for the survey). Questions in the survey ask respondents to provide information on a variety of characteristics about monitoring projects. Generally, these characteristics include basic contact information, locational information, indicators monitored, logistical information, quality assurance and controls, and staff and training information.

The survey was distributed on two levels – local and state/federal. In an effort to collect a greater amount and higher quality of local monitoring information, the Great Lakes Commission partnered with local groups in 14 key tributaries to Lake Michigan. The tributaries included all ten Areas of Concern (AOCs), as well as Grand Traverse Bay, Grand River, St. Joseph River, and Door County (see Appendix B for a list of project participants). The GLC conducted the survey of state, federal and other basinwide organizations.

Two workshops were conducted to provide training and technical assistance to project participants so that the survey could be administered as effectively as possible. At the first workshop, the survey, along with a set of supporting materials, was distributed to project participants. These materials were reviewed and subsequently adapted to reflect participant feedback. A process was established at the meeting, whereby participants committed to carry out the following steps:

- *Develop a contact list for delivering surveys.* Participants were encouraged to meet with their local advisory groups and develop a list of entities in the watersheds that might be conducting monitoring programs, including local municipalities, utilities, educational institutions, business/industry groups, environmental and conservation organizations and recreational groups among others.
- *Distribute surveys with informational materials.* Participants were subsequently sent a set of materials that could be tailored to their local area. Methods to encourage high response were also discussed.
- *Enter returned surveys into electronic format.* Participants were given a database template to be used for data entry. The final datasets were sent to the GLC for encorporation into the project database. The final database is being developed for public use on the Internet as a geographically-searchable database.
- *Follow up to encourage high response.* Several strategies were discussed to increase the response rate.

- *Report findings.* A framework and timeline were established for reporting on local survey results. These reports were submitted to the GLC for integration into this final report.
- *Final workshop.* A workshop was held to review the overall findings of the project and to share information and ideas about how local groups could build on the results in future projects.

A second meeting was held midway through the project to troubleshoot survey and reporting difficulties. The main difficulty was determined to be response rate. Following the meeting, GLC crafted a press release that the project participants adapted and sent out to local media outlets. This was used to create greater awareness of the project, thereby encouraging better response.

Local Methodologies

Each project participant tailored the general methodology to achieve the best results for their watersheds. The specific methodologies used by the project participants, along with general information about survey results, are provided below.

Grand Traverse Bay

Description of the Research Process

The purpose of this research project is to identify the overall state of ecosystem monitoring being conducted in the Grand Traverse Bay watershed. In addition to water quality monitoring, ecosystem monitoring includes collecting data on selected parameters that effect the biological, physical, chemical, and human health condition of the watershed**.** Parameters such as fish and wildlife habitat, wetland coverage, land use development patterns, construction of infrastructure, atmospheric deposition, climatic conditions, groundwater contamination, watershed hydrology, and others are useful in assessing the condition of a watershed.

Collaboration and Communication With Watershed Groups

The survey project was presented to the Grand Traverse Bay Water Quality Monitoring Team to solicit their support and assistance in identifying organizations to receive the survey. Promotion of the survey was also made at public meetings, monthly meetings with natural resource managers, monthly meetings with the Grand Traverse Regional Environmental Health Committee, and presentations about Grand Traverse Bay sponsored by Grand Traverse Bay Watershed Initiative (GTBWI).

Number of Entities Contacted and Number of Responses

The Grand Traverse Bay Watershed Monitoring Inventory Form was mailed to 96 selected organizations located in the Grand Traverse Bay Watershed.

Of the 96 organizations receiving the survey, 24 returned the survey. Of the 24 respondents, 17 administer a monitoring program.

Muskegon and White Lakes

Surveys were mailed to over 275 potential monitoring entities in the Muskegon and White Lake AOC/River Watersheds. All county level governments, drain commissions, health departments, road commissions and conservation districts were surveyed. Contacts with the PACs and other conservation organizations initially helped to form a mailing list of townships, planning commissions, schools, sport fishing/conservation and lake associations with an interest in water quality, habitat and environmental education projects. This mailing list was compiled and used in the survey. Through a network of conservation districts, individuals and organizations throughout the watershed, a list of individuals, businesses, city governments, schools and university contacts was developed and used in the survey. Personal contacts, phone calls and follow up mailings were performed as more information became available.

Of the survey contacts made, 70 responses were received by the Muskegon Conservation District. Of these, 23 responded with monitoring information. Thirteen of these respondents were from the Muskegon Lake AOC/River Watershed and eight were from the White Lake AOC/River Watershed. A total of 47 respondents indicated that they did not perform any monitoring.

Four public meetings were held to support the RAPs and two newsletters were developed in conjunction with the Muskegon and White Lake Public Advisory Councils to raise awareness and solicit participation for this project. The newsletters were mailed and/or distributed to over 2000 members of the public. An additional survey mailing about the occurrence of “projects” in the Muskegon River Watershed was completed to supplement knowledge about activities and opportunities which could be useful to the Muskegon River Watershed Assembly. A meeting to discuss public involvement in contaminated sediments remediation will be held in the White Lake area as part of this project as well. An educational brochure about Muskegon County watersheds (Muskegon and White being the two largest) is also being developed to promote watershed awareness and public involvement opportunities.

Grand River

Research began with contacting Grand Valley State University-Water Resources Institute (GVSU-WRI) and obtaining mailing lists for different individuals involved in water related projects that were already known to the Institute. This proved to be the best resource since the Grand River does not have a public advisory council or committee established at the time of this study.

A list was also comprised from the Michigan Water Environment Association’s 1998-99 membership directory. Surveys sent to these organizations were asked to provide information on monitoring that was above and beyond what they report for compliance purposes.

Contacts were obtained by searching through publications, reports, and news articles for individuals and groups that were in the media. Internet sites were also searched, but unfortunately most of the information found was outdated and websites did not give a good representation of the watershed as a whole. Another search method was the Know Your Watershed software published by Conservation Technology Information Center, which can be found at **http://www.ctic.purdue.edu/KYW/**. The information was obtained for local groups working within different watersheds. The publication date was in 1996, so some of the groups were no longer active. Other names came from individuals that completed the survey.

A total of 325 surveys were sent out in two bulk mailings. Additional surveys were mailed individually as more contacts were discovered. The University had 25 successful responses and 28 negative responses. The majority of surveys sent out were never returned. Inquiries were made by non-monitoring groups on the project, and results will be sent to them.

Kalamazoo River

In an effort to share responsibilities on this project, as well as avoid repetition of surveying, the Kalamazoo River Watershed Public Advisory Council (KRWPAC) partnered with a local project known as the Watershed Information Management Project (WIMP). This group seeks to compile monitoring data and store it in a publically accessible format. After several initial meetings with this group, it became evident that the decision making process between the two groups was preventing our project from commencing on schedule for our November 1, 1999 deadline. We decided to go ahead with our surveying efforts, and agree to share the information acquired with the WIMP group when the time had come.

Utilizing a mailing list obtained from the Michigan Department of Environmental Quality (MDEQ) for the Allegan Lake TMDL project, our first contact included a mailing of 272 surveys to the various contact persons on the list. Initial response yielded about 20 surveys. The surveys requested a two week turnaround time. At four weeks past the date they were mailed an intern conducted follow up calls. Most agencies did not respond to the surveys because they are not conducting any monitoring. We did receive a few surveys that were mailed or faxed back indicating that no monitoring efforts were taking place. The follow up calls did yield an additional four surveys.

A second mailing utilized a list obtained from the Kalamazoo Foundation, a private non-profit foundation that had recently held a Sustainable Community Watershed Conference. Using a list generated from those attending the conference, an additional 50 surveys were sent out. Response from this mailing yielded approximately five responses. Follow up calls did not yield any responses.

In early August, a press release was sent to the major newspapers in the Watershed as well as a few news-oriented radio stations. It is unclear as to how many of these publications actually ran the article. A few responses were received via phone, but these were general inquiry about the Watershed Council. No survey results were attained from the press release.

St. Joseph River

The first stage of the assessment was to identify various organizations that might be monitoring for information on the St. Joseph River watershed, either on water, land, wildlife or any other benchmark. Numerous telephone calls were made to speak with individuals involved in some kind of watershed monitoring. Newspapers serving all watershed counties except Berrien published the press release, proposed by the GLC. The next step was to utilize the survey form designed by the GLC/EPA. Telephone interviews were conducted with several individuals. If they did not return the survey form, the details of their programs were not made available. Comments from some of the organizations that did not return forms are included in the Excel spreadsheet under the comment column. A few personal interviews were conducted and these actually are most effective way to conduct surveys but time or lack of available resources did not permit this as a routine method. The names of the contacts are listed in the Excel spreadsheet even if they did not respond. The ones that responded with a completed form are designated in italics.

A total of about 40 organizations were contacted but only nine completed survey forms were returned. The organizations that were contacted included county health departments, wetland conservation groups, nature centers, volunteer “water watchers”, lake and stream association members, river environmental groups, “steelheaders”, county conservation offices, colleges and newspapers. The small number of returned forms reflects what appears to be a low level of formal programs that are in place that possess the discipline and resources required to monitor the parameters listed on the survey form. For example, only one organization, “Water Watcher”, of Indiana, reported monitoring Atrazine and Acetichlor.

Grand Calumet River

An initial list of likely monitoring organizations or contact people was constructed from the membership of the Citizens Advisory for the Remediation of the Environment (CARE) Committee, the Interagency Task Force on *E. coli* member lists, participants in the TMDL stakeholder process, and other local partnership efforts. The Indiana Department of Environmental Management (IDEM) Volunteer Monitoring Coordinator and the Indiana Department of Natural Resources Hoosier Riverwatch Coordinator was also consulted for a list of local participants in their volunteer water quality monitoring programs. The Riverwatch program did supply a list of past participants in their projects in Lake, Porter, and LaPorte County, Indiana. This information confirmed that in fact, no volunteer water quality or aquatic biota monitoring actually occurs in the Grand Calumet River system. This is most likely the result of the real or perceived dangers of exposing volunteers to a waterbody with a large accumulation of highly contaminated sediments. Despite this limitation, a substantial list of contacts and organizations was constructed. Groups which might be collecting water quality data in other Lake Michigan tributaries and those which might collect other types of environmental information where added to the list. An internet search was conducted for local chapters of national organization such as Audubon and Sierra Club which might participate in bird and wildlife counting activities. Faculty members involved in ecological or environmental research at local universities were also included. In addition, lists of local governments such as park departments, water departments, and others were provided by the Northwest Indiana Regional Planning Commission. Most of the lists provided by others provided addresses only.

In addition to Internet and phone research, information about this project was presented at a number of local meetings and partnerships. Members of the CARE Committee, the Interagency Task Force on *E. Coli*, and the TMDL stakeholders were informed of the project and advised that they would likely be receiving surveys. Presentations and surveys where also distributed at the annual meeting of the Indiana Hub of the Great Lakes Aquatic Habitat Network, a consortium of local environmental organizations and individuals interested in environmental issues.

An initial mailing of letters, fact sheets, and surveys was distributed to 20 individuals and organizations. Since project funding was actually received by Indiana University as a member of the *E. Coli* Task Force, the letters where sent on Task Force letterhead and signed by Kathy Luther as the Task Force Co-Chair. No responses where received as a result of this initial mailing.

Limited follow up calling was done to those organizations known to be conducting monitoring. A total of two responses were received as a result of this calling effort. Because of earlier decisions regarding project funding, there was insufficient staff time dedicated to this project to permit more extensive calling efforts. Based on conversations with other project participants, 10 percent seems to be a fairly consistent response rate. Follow up phone calls indicated that many recipients did not consider the work they might be doing to be monitoring. This may be one reason for poor survey response rates.

After a mid-term Lake Michigan Tributary Monitoring Project participant meeting in Chicago revealed that GLC was having limited response from state and federal agencies, an effort was made to contact local branches ofsome of these agencies by phone and fax out surveys. Surveys where sent to the IDNR, to Illinois-Indiana Sea Grant, and the USGS Research Station at the Indiana Dunes National Lakeshore. No responses where received as a result of these surveys. IDEM completed survey forms for those partnerships and organizations for which IDEM is a substantial participant. Despite limited responses to surveys IDEM is confident that a comprehensive list of state agency efforts will capture most if not all ongoing water quality monitoring that is occurring in the Grand Calumet River and this Area of Concern. As a result staff time was largely dedicated to completing online the surveys for all IDEM monitoring programs.

Initially, IDEM believed that all information necessary for the Tributary Monitoring Project would be collected in the TMDL process. While this was not the case, some important data was discovered which might not have been learned from the survey project. Information was collected about data that National Pollutant Discharge Elimination System (NPDES) dischargers have collected during discrete time periods as part of special projects. This information is not part of ongoing continuous data collection efforts or any organized monitoring programs and so is not a good fit with the database format of this project. The information was included because it might be useful for any efforts to compile historical data. The regular monitoring of operations and outfalls which NPDES holders undertake as part of the regulatory requirements of their permits is not included in this report. However, it may be useful to remember that information of this type is collected regularly and reported to state agencies.

Waukegan Harbor
The following steps were implemented prior to contacting a company or agency:

- A press release was sent to all local newspapers. Lake County Chamber of Commerce Newsletter published the press release.
- Announcements of the survey were made at the Audubon Society, Waukegan Harbor Citizens Advisory Group, and Liberty Prairie Conservancy meetings.
- Networking was done by telephoning approximately 150 companies, agencies, schools, and lead contacts furnished by telephone contacts. For future reference of sources for information, a database of 52 contacts was developed. Some contacts expressed interest in being a part of future monitoring programs. There were eight surveys returned out of fourteen mailed.

Milwaukee River
Meetings were held with Wisconsin Department of Natural Resources (WDNR) staff, RAP leaders, and others to develop a list of stakeholders and managers working in the basin (DNR, County Land Conservation Departments, University of Wisconsin-Extension Offices, Non-Governmental Organizations (NGOs) etc.). Identified organizations were then contacted by telephone to describe the goals and objectives of the project. Some of the entities contacted provided valuable information regarding their monitoring activities and mentioned some other entities that should be contacted. In most cases however this was not the case, either the groups were no longer active or they were monitoring for compliance with state and federal regulations. In total, over 200 entities were contacted with only 63 actively monitoring. However, of the 63 active programs, only 16 were applicable and responded to this project. After further investigation it was apparent that many of the applicable programs were connected in some way or form to state agencies, mainly the DNR and UW-Extension.

Sheboygan River
A procedure similar to the one used for the Milwaukee River watershed was used to collect information on the Sheboygan River watershed. In total, over 100 entities were contacted with only 28 actively monitoring. However, of the 28 active programs, only 12 were applicable to this project, as many were subsets of a broader program. For example, Testing the Waters involves numerous schools, teachers, and students in the basin. After further investigation it was apparent that many of the applicable programs were connected in some way or form to state agencies, mainly the DNR and the UW-Extension.

The two largest and most active monitoring programs in the Sheboygan River Basin, Testing the Waters and the Pigeon River Water Action Volunteers (WAV), fit the trend previously mentioned. The DNR and the UW-Extension have played active roles in providing equipment and technical guidance for both programs. The Testing the Waters program incorporates local high school and middle school students to actively monitor various tributaries throughout the Sheboygan River Basin (Pigeon, Sheboygan, and Mullet River Watersheds). This program has been very successful, involving several schools over the past eight years. The WAV program, very similar to the Testing the Waters program, utilizes local citizens to monitor water quality. WAV monitoring teams consisted of either adult volunteers or school classes. In both cases, the DNR and UW-Extension provided the initial support and training to develop these programs, but now rely on their local team leaders (teachers and others) to facilitate the efforts. This initial involvement by the DNR and UW-Extension (training, quality control, and equipment) has provided the assurance that the data collected by Testing the Waters and WAV are deemed worthy for ecological assessment, as stated by various stakeholders.

Other smaller programs were also found monitoring in the Sheboygan River Basin. These programs or projects involved land trust and conservation offices, local colleges/universities, as well as a few industrial facilities.

Fox-Wolf Basin
Fox-Wolf Basin 2000 established a list of 131 individuals or entities thought to be conducting some kind of ongoing monitoring program in the basin. This list was derived from our database--focusing on agencies, organizations and university researchers. Additional contacts were provided through a Wisconsin Department of Natural Resources Water Action Volunteer (WAV) database.

Cover letters and survey forms were distributed to those for whom addresses were readily available. After waiting a few weeks, follow-up calls were made to selected contacts. Additional e-mail requests were made in early January prior to the compilation of this report. Seventeen responses were received from eight different individuals and entities. The lack of adequate monitoring in the Fox-Wolf basin has long been lamented by citizens and resource managers alike. However, it is likely there are additional monitoring programs being conducted in a Basin of this size. The limited response in this survey is believed to be more the result of FWB 2000 not having the staff or time available to be more diligent in making additional, repeated contacts.

Door County
Research as to the degree to which monitoring or collecting of data is done on a regular basis was conducted in three modes: personal contact; written communications to determine what, if any, monitoring was being done; and personal interviews with key personal in local and state agencies.

There are no specific nonprofit or volunteer watershed groups in the area, other than two lake associations.

Pursuant to 21 telephone and personal contact interviews, ten letters of inquiry were sent to local organizations and individuals. Personal contact interviews were conducted with three staff personal within the Department of Natural Resources, each with different areas of responsibility. Companies located in Sturgeon Bay's Industrial Park gave indications that their activities were not of a nature that monitoring would be a concern.

Menominee River
A procedure similar to the one used for the Milwaukee River watershed and Sheboygan River watershed was used to collect information on the Menominee River watershed. Many of the national environmental organizations (Isaac Walton League, Trout Unlimited, etc) had representatives or chapters in the basin, but were not actively monitoring at the present time. In total, over 50 organizations were contacted with only 8 actively monitoring. After reviewing the list with County Land Conservation managers and WDNR staff, it was apparent that the list was comprehensive.

Manistique River

Description of the research process

Schoolcraft County Economic Development Corporation coordinated research to determine groups, agencies, businesses, governmental entities, and individuals conducting research and monitoring within the Manistique River Watershed.

The following was the process used to collect data for this process:

1) List of potential contacts generated by the Corporation and Manistique River/Harbor Public Advisory Council.
2) Initial mailing sent to entire mailing list. Mailing included an introductory letter, background document describing basin-wide project, and a survey form. All three of these documents were developed by the Great Lakes Commission with comment by all partners.

3) Follow-up mailings of the same packets were delivered to new persons identified by respondents identified and contacted during step two.
4) Surveys returned to the Corporation were entered into the required Excel spreadsheet. Respondents were contacted for additional information if needed.
5) James Anderson met with Michael Tansy, chairperson of the Manistique River Watershed, and director of the Seney National Wildlife Refuge, and George Lyon with the Luce-Mackinac-Schoolcraft Soil and Water Conservation District office.
6) Telephone or personal contacts were made to recipients of the survey who did not respond to determine their level of monitoring activities within the Watershed.

Collaboration / communication with the public advisory council or other watershed groups

During the course of the research the Corporation worked with the Manistique River/Harbor Public Advisory Council to brainstorm monitoring activities occurring within the Watershed, and to develop an initial mailing list for the survey instrument.

The Corporation met with the lead staff person with the local Soil and Water Conservation office, and the chairperson of the organization and director of the Seney Wildlife Refuge to discuss their activities within the watershed. Both shared that beyond the activities of the Refuge, there are very few monitoring activities happening within the watershed. The response from the survey instrument verifies that the assessment made by Mr. Tansy and Mr. Lyon was correct.

Other outreach efforts

In addition to the above activities, a press release developed by the Great Lakes Commission was modified for local informational content, and sent to the local media including radio (WTIQ), and the local newspapers - *Pioneer Tribune* (Manistique / Schoolcraft County), *Munising News* (Alger County), and the *Newberry News* (Luce County). James Anderson, executive director provided updates and information at Corporation board meetings concerning the project which were covered by the media, and discussed the project during a quarterly half-hour interview on WTIQ AM 1490 Community Focus program.

Number of entities contracted and number of responses

Of the 34 surveys sent out, six (6) responses were received. George Lyon with the Soil and Water Conservation indicated that he did not believe either dam operator was involved with any monitoring activities.

General comments on results

Only five surveys were returned indicating that a rather large watershed has very little monitoring or coordination of conservation activities occurring within it. Further, the data returned indicated that most monitoring is for regulatory requirements, with some additional data collection beyond the required level. There does not appear to be any monitoring in terms of land use, soil, and very little monitoring of Fish and Biota / Wildlife beyond that of the Seney National Wildlife Refuge and the United States Department of Agriculture - Hiawatha National Forest.

In terms of the indicators being collected, all 18 indicators are being collected by at least one organization - City of Manistique, Department of Public Works. Further, most monitoring appears to be completed by paid staff who are trained in data collection methodology as well as quality assurance / quality control methods.

Further, the Corporation was surprised to find that only one of three universities in the region has any interest in conducting research within the watershed, and the only effort is driven primarily due to the contamination of the lower watershed with PCB’s.

Federal and State Data Collection

The GLC was primarily responsible for collecting data from federal, state, and other organizations conducting monitoring programs basinwide. This was accomplished through two efforts — a survey, and supplemental data search. First, the GLC, in consultation with project participants and members of the Lake Michigan Monitoring Coordination Council (LMMCC), developed a list of federal and state entities that were likely to be conducting monitoring efforts in the basin (see Appendix D for the LMMCC membership list, and Appendix E for a list of survey contacts). In an effort to maintain efficiency, every effort was made to select specific contacts who could respond generally about monitoring programs in their agency, or who would collect information from relevant people in their agency. Follow up phone calls and e-mails were made to non-respondents to solicit a higher response rate. These phone calls led to further contacts (sometimes in other agencies), and additional surveys were distributed. In addition, the survey form was transformed into a web-based format to ease completion by respondents. This generated further responses, as agency contacts often asked multiple people within their agency to complete the web-based form. From an initial distribution of 72 surveys, the GLC received 27 responses. An accurate response rate cannot be calculated, since some agencies returned several surveys (some not directly solicited), while others returned none. The full database of survey responses (including local responses) can be obtained upon request.

The data received from the surveys was supplemented with information on monitoring collected through a general information search. This consisted of a general web review, as well as follow-up from conversations with agency and participant contacts. In many cases, the information collected through this method made it unnecessary to pursue further contacts with specific agencies. Several databases of monitoring information were discovered through this process. The most useful database was the *Better Assessment Science Integrating Point and Nonpoint Sources (BASINS)* system developed by Tetra Tech, Inc. for the U.S. EPA, Office of Water. This system consolidates a number of federal databases to allow easy extraction and use of ecological information on a watershed basis. Several datasets were used in the analysis for this report.

Datasets used to provide monitoring information for this report (including those extracted from BASINS and those obtained elsewhere, are included below. Where possible, dataset summaries are taken directly from metadata provided with the dataset.

The Storage and Retrieval (STORET) System
This dataset provided statistical summaries of water quality monitoring for 47 physical and chemical-related parameters. The parameter specific statistics were computed by station for five-year intervals from 1970 to 1994 and a three-year interval from 1995 to 1997. The data are contributed by a number of organizations including federal, state, interstate agencies, universities, contractors, individuals and water laboratories. Information was extracted from the STORET system for analysis of monitoring coverage for all LaMP pollutants, bacteria, nutrients, and some physical characteristics.

Permit Compliance System (PCS)
PCS is a national computerized management information system that automates entry, updating, and retrieval of National Pollutant Discharge Elimination System (NPDES) data and tracks permit issuance, permit limits and monitoring data, and other data pertaining to facilities regulated under the NPDES program. PCS records water-discharge permit data on more than 75,000 facilities nationwide.

The NPDES permit program regulates direct discharges from municipal and industrial wastewater treatment facilities that discharge into the navigable waters of the United States. Wastewater treatment facilities (also called "point sources") are issued NPDES permits regulating their discharge. Information on the point locations of sites reporting discharges from 1991 through 1996 were included in the analysis for this report.

Toxic Release Inventory (TRI)
This database contains data on annual estimated releases of over 300 toxic chemicals to air, water, and land by the manufacturing industry.

Industrial facilities provide the information, which includes the location of the facility where chemicals are manufactured, processed, or otherwise used; amounts of chemicals stored on-site; estimated quantities of chemicals released; on-site source reduction and recycling practices; and estimated amounts of chemicals transferred to treatment, recycling, or waste facilities.

The TRI data for chemical releases to land are limited to releases within the boundary of a facility. Releases to land include landfills; land treatment/application farming; and surface impoundments, such as topographic depressions, man-made excavations, or diked areas. Air releases are identified as either point source releases or as non-point (i.e. fugitive) releases, such as those occurring from vents, ducts, pipes, or any confined air stream. Surface water releases included discharges to rivers, lakes, streams, and other bodies of water. In addition, the database covers releases to underground injection wells (where chemicals are injected into the groundwater) and off-site transfers of chemicals to either publicly owned treatment works (POTWs) or any other disposal, treatment, storage, or recycling facility.

For use in the assessment for this report, information on the locations of facilities discharging pollutants through any of the above media streams from the years 1987 through 1995 were included.

National Sediment Inventory
This dataset describes the accumulation of chemical contaminants in river, lake, ocean, and estuary bottoms and includes a screening assessment of the potential for associated adverse effects on human and environmental health. The U.S. EPA evaluated more than 21,000 sampling stations nationwide using sediment chemistry data, chemical residue levels in edible tissue of aquatic organisms, and sediment toxicity data. Of the sampling stations evaluated, 5,521 stations were classified as Tier 1 (associated adverse effects are probable), 10,401 stations were classified as Tier 2 (associated adverse effects are possible, but expected infrequently), and 5,174 stations were classified as Tier 3 (no indication of associated adverse effects). Ninety-six watersheds were identified as areas of probable concern for sediment contamination. U.S. EPA believes that these watersheds represent the highest priority for further ecotoxicological assessments, risk analysis, temporal and spatial trend assessments, contaminant source evaluation, and management action because of the preponderance of evidence in these areas (although further evaluation is necessary). Also see the related report entitled the *Incidence and Severity of Sediment Contamination in Surface Waters of the United States, Volume 1, National Sediment Quality Survey* (EPA 823-R-97-006, **http://www.epa.gov/OST**) that was published in September 1997.

Stations monitoring for sediment chemistry data, chemical residue levels in edible tissue of aquatic organisms, and sediment toxicity data were used for the inventory. For this report, information on monitoring station locations, monitoring agency, and type of sampling conducted (i.e. sediment chemistry or biotoxicity/tissue residue).

U. S. Geological Survey Gage Stations
This dataset contains the locations and summary data from USGS stream gaging stations. The gage data were retrieved from the Gage File database. These stations are used primarily to collect continuous stream flow and water level information on target waterbodies. Only gage locations were used in this report.

Aerometric Information Retrieval System (AIRS)
The AIRS system inventories and summarizes air pollutant data from air monitoring stations throughout the United States. The system is funded and maintained by U.S. EPA Office of Air Quality Planning and Standards (OAQPS). The system contains information about and from stations that monitor the following criteria pollutants:

CO - carbon monoxide (gas)
NO2 - nitrogen dioxide (gas)
O3 - ozone (gas)
SO2 - sulfur dioxide (gas)
PB - lead (a constituent of particulate matter)
PM10 - particulate matter (particles smaller than 10 micrometers)

Additionally, AIRS data includes emissions estimates for two more pollutants:

PT - particulate matter (total, all particle sizes - reported in lieu of PM10)
VOC - volatile organic compounds (precursors that can lead to the formation of ground level ozone)

Data on site locations and pollutant monitored were extracted for use in this report.

National Oceanic and Atmospheric Administration (NOAA) Weather Stations and Weather Data Management (WDM) Sites
This data set provides a location map in ARCVIEW Shapefile format of weather stations and WDM stations for the entire United States and U. S. territories. The spatial data was prepared from the National Climatic Data Center Hourly Precipitation database available from EarthInfo, Inc. (**http://www.earthinfo.com/earthinfo/**). The shapefile is prepared and distributed by U.S. EPA regions or states. Information on site locations of weather stations was used for this report.

Fish and Wildlife Consumption Advisory Database
The 1996 update for the database, *Listing of Fish Consumption Advisories*, is now available from the U.S. Environmental Protection Agency. This database includes all available information describing state-, tribal-, and federally issued fish consumption advisories in the United States for the 50 states, the District of Columbia, and four U.S. Territories, and has been expanded to include the 12 Canadian provinces and territories. The database contains information provided to U.S. EPA by the states, tribes, and Canada as of December 1996. This includes advisories issued by several Native American tribes.

The number of advisories in the United States rose by 453 in 1996 to a total of 2,193 representing a 25 percent increase over 1995. The number of waterbodies under advisory represents 15 percent of the nation's total lake acres and 5 percent of the nation's total river miles. In addition, 100 percent of the Great Lakes waters and their connecting waters and a large portion of the nation's coastal waters are also under advisory. The number of advisories in the United States increased for four major contaminants (mercury, PCBs, chlordane, and DDT). In 1996, the U.S. EPA contacted health officials in Canada in an effort to identify fish consumption advisories in effect. In Canada, a total of 2,617 advisories were in effect in 1996. All of the Canadian advisories resulted from contamination from five pollutants: mercury, PCBs, dioxin/furans, toxaphene, and mirex. Ninety-six percent of all the advisories resulted from mercury contamination in fish tissues. In addition, 87 percent of the advisories were issued by the provinces of Ontario and Quebec. Information on the location of advisories, species affected, and flagged pollutants were used in this report.

Lake Michigan Mass Balance (LMMB) Monitoring Sites
This is an unpublished dataset that contains information on sites providing information for the Lake Michigan Mass Balance Project. Information includes locations, and purposes for sampling stations, project names and organizations, and indicators analyzed. The information is contained in three separate datasets, and linkages are based only on project names. Data quality is undefined. Information for this report was extracted from this dataset for monitoring locations, media and pollutants monitored, and organizations conducting the monitoring. The sample data itself has been quality assured and is available upon request from GLNPO.

National Water Quality Assessment Monitoring Sites (NAWQA)
This dataset includes the monitoring stations used in the Western Lake Michigan Drainages study unit for the NAWQA program. Information was collected through the study unit's online database, found through **http://wwwdwimdn.er.usgs.gov/nawqa/index.html**. Information included station identification, location, and flags for one of four types of monitoring conducted: surface water, ground water, sediment and tissue, and biological. More extensive data can also be obtained from this site, including parametric measurements.

Additional Federal/State Datasets

Several monitoring data sets were discovered just prior to final publication of this report. Discussion and general analysis of these sets have been included in the report, but in the interest of time, geographic analysis of monitoring site locations was not completed. Geographic locations of monitoring stations in these data sets will be included in the online version of the monitoring inventory when it is released. General information on these data sets are included below.

Regional Toxic Air Emissions Inventory
This is a multijurisdictional inventory of point, area, and mobile sources of toxic air emissions that have the potential to impact environmental quality in the Great Lakes basin. This initiative was undertaken through an intergovernmental partnership involving the eight Great Lakes states, the province of Ontario, and the U.S. Environmental Protection Agency (U.S. EPA). The objective of this ongoing initiative is to present researchers and policy makers with detailed, basin wide data on the source and emission levels of 82 toxic contaminants. Source and emission levels are projected by each state or province using the *Regional Air Pollutant Inventory Development System (RAPIDS).* The most recent inventory report uses 1996 data and can be found at: **http://www.glc.org/air/1996/1996.html**.

Integrated Atmospheric Deposition Network (IADN)
The Integrated Atmospheric Deposition Network is a joint effort of the United States and Canada to measure atmospheric deposition of toxic materials to the Great Lakes. This network includes a number of stations throughout the Great Lakes, but only one is found in the Lake Michigan basin at Sleeping Bear Dunes National Lakeshore. This station monitors for PCBs, chlorinated pesticides, PAHs, and trace metals in air and precipitation. This site was also included in the analysis of the Lake Michigan Mass Balance Project. Please see discussions on that program for more details.

Sea Lamprey Assessment
Through the Great Lakes Fishery Commission, the Sea Lamprey Integration Committee (SLIC) was established to monitor and control Sea Lamprey infestation throughout the Great Lakes. The Sea Lamprey Assessment Task Force within SLIC establishes plans for monitoring to assess the extent of infestation. In general, tributaries of the Great Lakes systematically are assessed for abundance of sea lamprey larvae (quantitative surveys) and distribution (qualitative surveys) to determine when and where lampricide

treatments are required and effectiveness of past treatments. Results of these assessments are published in annual reports.

R/V Lake Guardian **Sampling**

The U.S. EPA's Great Lakes National Program Office (GLNPO) annually tours the Great Lakes and samples for phyto- and zooplankton at specified locations. The *R/V Lake Guardian* is used to conduct sampling tows at different depths to obtain data on changes in plankton populations. In addition, the vessel takes a set of standard baseline measurements including conductivity, temperature and depth.

Lakewide Assessment Plan for Lake Michigan Fish Communities

This plan was developed through the Great Lakes Fishery Commission (GLFC) by Departments of Natural Resources from Wisconsin, Michigan and Illinois, as well as the USFWS and USGS-BRD. The plan establishes guidelines for annual sampling of lake trout, chinook salmon, and burbot populations throughout Lake Michigan. For lake trout and burbot, six sampling sites are randomly selected from within eleven regions each year for a total of 66 sampling locations. For chinook salmon, randomly-selected sites are selected along the length (south to north) of the lake in the spring and summer, with 22 sites selected in each season.

Status and Trends of Prey Fish Populations in Lake Michigan, 1999

This report from the USGS Great Lakes Science Center details the monitoring and findings related to sampling of prey fish populations through 1999. The surveys are performed using standard 12-meter bottom trawls towed along contour at depths of 9 to 110 m at each of seven to nine index transects. Information is collected on abundance, species composition, population characteristics, and general fish health.

3. Inventory Results

The ultimate result of nearly one year's work by the GLC, 14 local tributary groups, and other stakeholders, this report represents an inventory of ecological monitoring projects throughout the Lake Michigan basin. The results that follow originate from two basic sources — the survey data, and a supplementary search of relevant datasets. All data is combined into analyses for each of the 14 tributaries, as well as one for the open waters of Lake Michigan.

General Survey Results

Altogether 334 surveys were returned from efforts made by local groups and the GLC. Agencies from all levels of government (federal, state, and local), as well as business, academic, and volunteer organizations from diverse regions of the basin participated in this survey, and added their information to the inventory. Of the responses, 63 percent of the projects primarily monitor water, 5 percent monitor land, 2 percent monitor air, 3 percent monitor soils, 18 percent primarily monitor biota or wildlife, and 9 percent primarily monitor other media (see Figure 2). See specific watershed chapters for discussions about general monitoring characteristics. The frequency of monitoring broke down as follows: daily – 6 percent, weekly – 8 percent, monthly – 10 percent, semiannually – 12 percent, annually – 16 percent, other – 48 percent. Projects staffed the monitoring as follows: paid staff – 65 percent, volunteers – 17 percent, students – 11 percent, other – 7 percent (see Figure 3). The number of staff on monitoring projects range from one to 1000, with the median equal to three people. Nearly 93 percent of the programs provide some sort of training to staff. Budgets for the monitoring projects surveyed range from zero to $12 million, with a median budget of $15,000. Nearly 63 percent reported that funding for the monitoring project was relatively reliable.

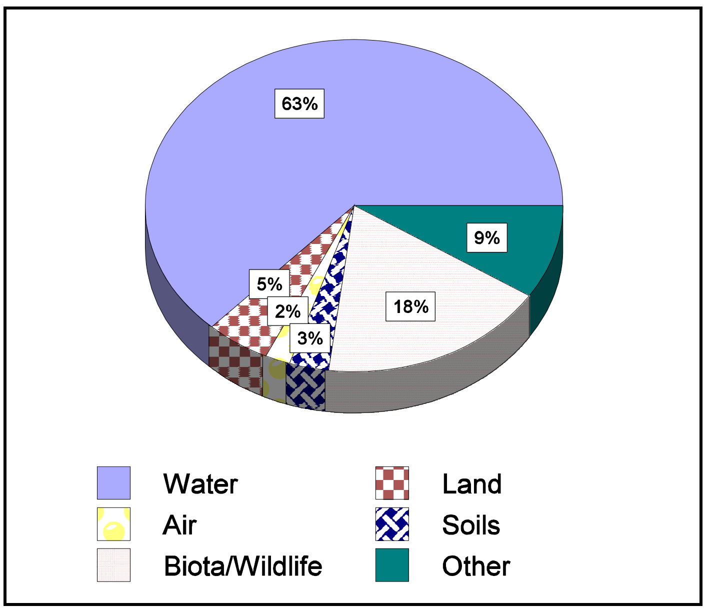

Figure 2. Proportion of survey responses by the primary medium monitored.

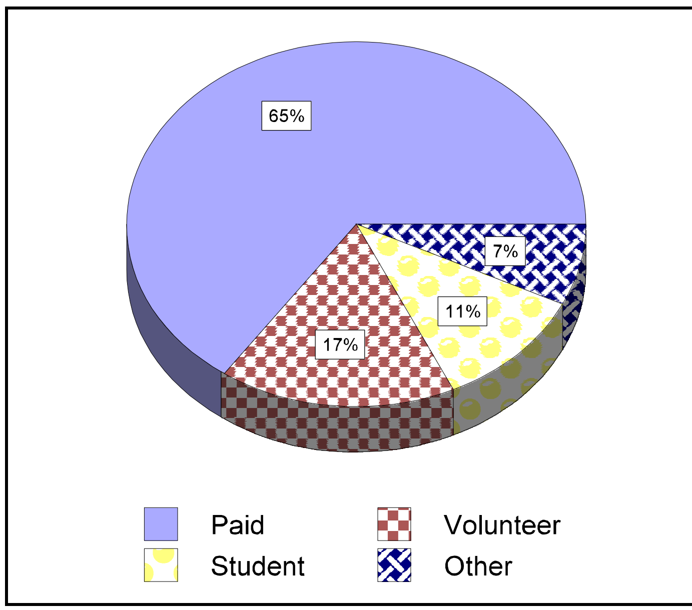

Figure 3. Proportion of survey responses by the type of monitoring staff.

Results Framework

The following chapters contain the analysis of inventory results for all 14 tributaries and the open waters of Lake Michigan, as well as generalized projects which cover multiple watersheds. The chapters are segmented as follows:

- Background
- LaMP pollutants
- Nutrients and bacteria
- Meteorological and flow monitoring
- Sediments
- Fish contaminants, fish health, and aquatic nuisance species
- Benthos monitoring
- Air monitoring
- Wildlife monitoring
- Land use
- Local assessment

Information in the background and local assessment sections was provided by the project participants, with editing by GLC to establish a continuity of flow. The other results-based sections contain integrated information from local project participant surveys, GLC surveys, and external datasets. Where possible, data is geographically displayed. However, each section discusses all monitoring projects, including those for which no specific geographic information was available.

13. Fox-Wolf River Basin

Background

The Fox-Wolf River basin of Northeast Wisconsin is a 6,400 square mile drainage area with three distinct sub-basins: the Wolf River, the Upper Fox and Lower Fox River. The Wolf and Upper Fox Rivers drain south and east (respectively) into the Lake Winnebago "pool" lakes and then north through the Lower Fox River to the bay of Green Bay. The Fox-Wolf Basin is the largest drainage basin to Lake Michigan and the third largest to the Great Lakes.

For purposes of this report, the discussion will address all three sub-basins and Lake Winnebago. However, the graphic display and majority of the discussion will focus on the Lower Fox River watershed. Lower Green Bay is also part of the AOC in this area, however, the bay is assessed as part of greater Lake Michigan Open Water chapter. Please see that chapter for further information.

Status of Watershed Management Efforts in the Study Area

Watershed management in the Fox-Wolf basin is conducted under a variety of program initiatives – primarily Wisconsin's Nonpoint Source Pollution Abatement Program (a.k.a. the Priority Watershed Program) and the Wisconsin Pollution Discharge Elimination System program. Ten of the basin=s 41 watersheds have been identified as priority watersheds. County Land Conservation Departments are provided with state funds for staff and overhead to conduct watershed inventories, develop management plans, contact landowners, and offer cost-share funds to install BMPs.

Funds are also available to other local units of government in urban or urbanizing areas of the watershed. Recently, this program has undergone a re-design which has yet to be completed. No additional watersheds are expected to be selected under the new program, but efforts will continue through local governments on a more limited scope and time frame.

Many other local, state and federal initiatives work on some component of watershed management in the Fox-Wolf basin, too numerous to mention in this introduction. Initiatives range in function from voluntary cost-share programs to local ordinances to state and federal permitting. A recent reorganization of the Department of Natural Resources has established geographic management units (GMUs) designed to better coordinate programs and involve all agencies and individuals. GMU (or Basin) Partner Teams have been established in the Upper Fox, Lower Fox and Wolf River Basins.

Pollutants of Concern

Aquatic Monitoring

Monitoring coverage for LaMP pollutants reported into the STORET system is shown in Figure 43. This maps indicates that stations exist for two (mercury and PCBs) of seven critical pollutants, six out of ten pollutants of concern, and none of the listed emerging pollutants. Monitoring for all pollutants is relatively light compared to other watersheds in this analysis. The monitoring is heaviest along the lowest section of the Fox River where it flows out into Green Bay. There are 12 stations monitoring mercury at our near the Fox River outfall, while there are 28 stations for the rest of the Fox-Wolf basin (four in the Lower Fox, three at the entrance and exit of the Fox River to Lake Winnebago, three in the Upper Fox, and 18 in the Wolf River watershed). Ten PCB stations have been placed along the Lower Fox, with one on the shore of Lake

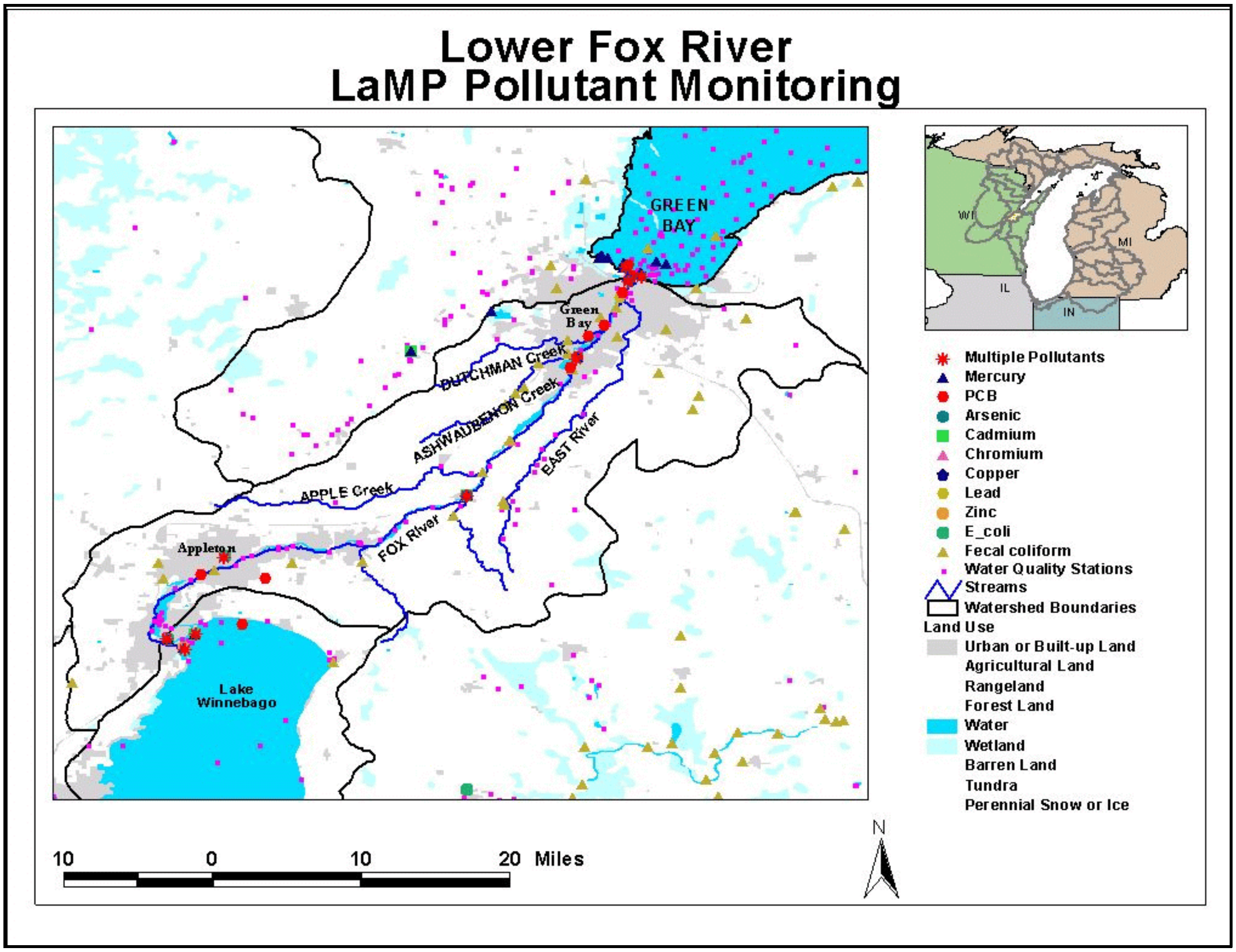

Figure 43. The Lower Fox River watershed with ambient water quality and bacteria monitoring stations from U.S. EPA's STORET system displayed by indicators measured.

Winnebago. The stations monitoring for LaMP pollutants are maintained by WDNR, U.S. EPA (3 programs), COE, USGS-WRD (NAWQA and baseline stations), or EPRI.

In addition, surveys indicate that the Green Bay MSD monitors for all LaMP pollutants with the exceptions of dioxins/furans, hexachlorobenzene, PAHs, and atrazine. This monitoring is conducted on the Lower Fox River at its outflow to Green Bay. Also, the University of Wisconsin-Stevens Point tracks atrazine in the Tomorrow-Waupaca River watershed.

Pollutant Release Monitoring

An examination of Permit Compliance System and Toxic Release Inventory reporting locations in the Fox-Wolf basin indicates a large number of monitoring locations for potential pollution sources throughout the basin (see Figure 44). Clusters of these locations can be found all along the Lower Fox River, as well as in Oshkosh on the western shore of Lake Winnebago, in Fond du Lac on the south shore, and on the shore of Shawano Lake in the Wolf River watershed.

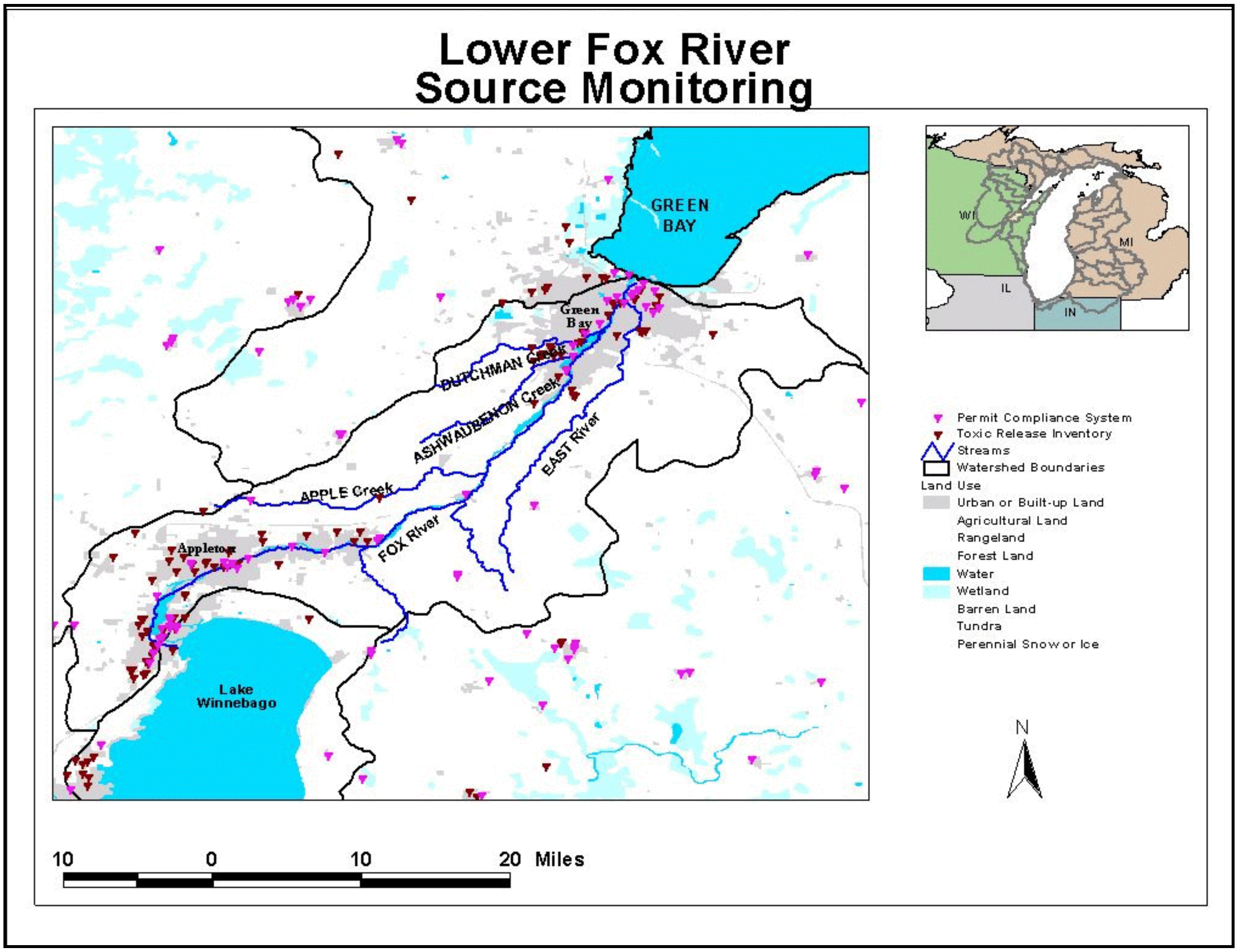

Figure 44. Lower Fox River watershed with pollutant sources from the Permit Compliance System and Toxic Release Inventory databases indicated.

Nutrients and Bacteria

There are more than 120 water quality monitoring stations within the Lower Fox River watershed listed in the STORET system. An additional 720 stations are located throughout the remaining watersheds in the Fox-Wolf basin. Also, there are a large number of stations in the near shore region of Green Bay. A vast majority of these stations (shown in Figure 43) monitor for some form of nitrogen and phosphorus, the chief nutrients impacting water quality. Thus, where monitoring stations exist, they are likely tracking nitrogen and phosphorus. The density of stations is greater at the Fox River outfall to Green Bay, but the rest of the stations are distributed fairly evenly throughout the basin. According to our surveys, there are several other organizations in the basin monitoring for nutrients. These include the Brown County Land Conservation Department, the University of Wisconsin-Stevens Point, the Green Bay MSD, Waupaca County Land Conservation Department, University of Wisconsin-Milwaukee, Green Bay RAP, and Green Bay Public Schools WAV.

Eleven stations monitor *E. coli* in the Fox-Wolf basin — three in the Lower Fox, six in the Upper Fox (including three on Lake Butte Des Morts), and two in the Wolf watershed. All 11 stations are maintained by WDNR. Monitoring for fecal coliform is significantly more extensive. About 120 stations can be found throughout the basin. As with other monitoring coverage in the basin, monitoring of fecal coliform levels is

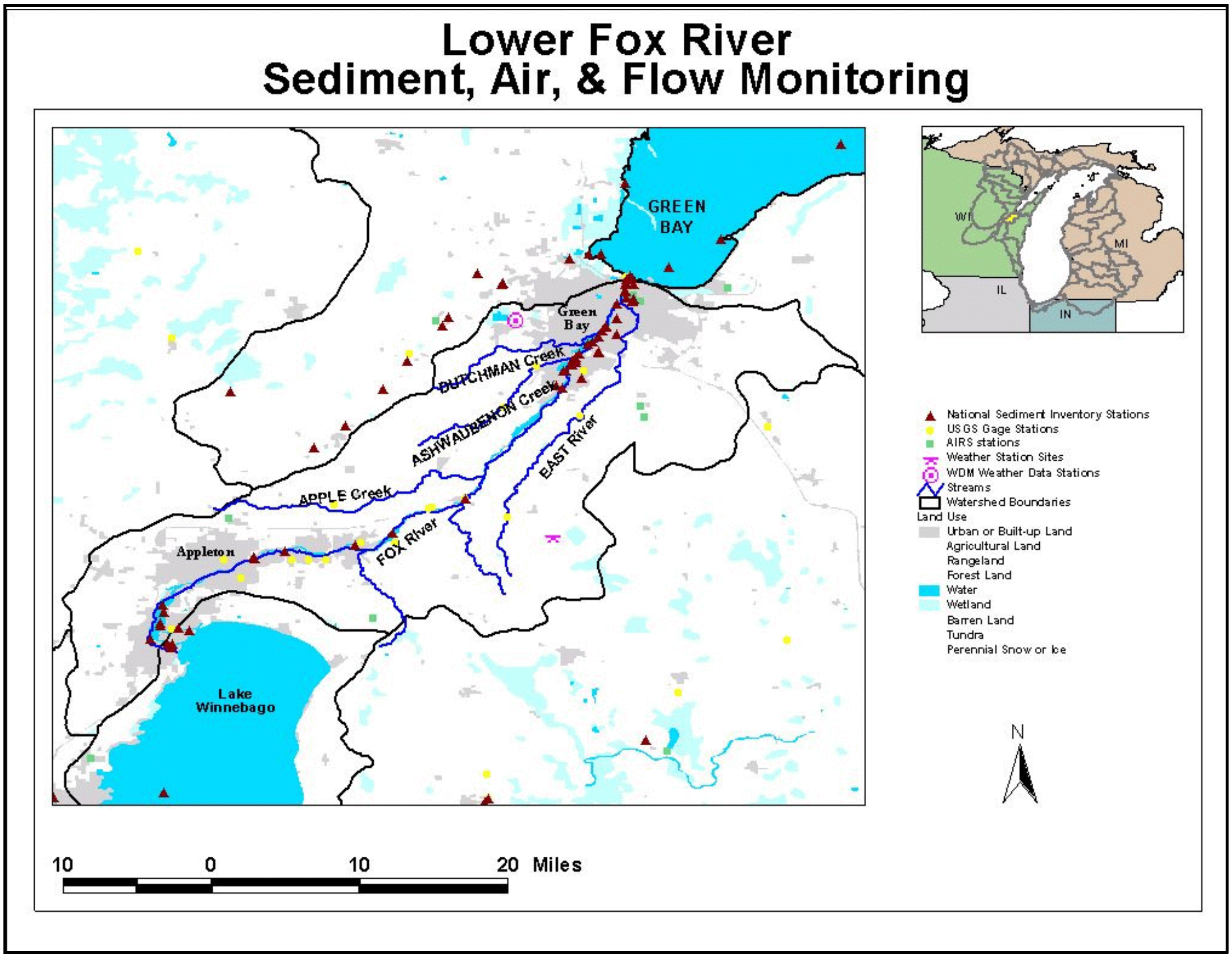

Figure 45. Lower Fox River watershed with National Sediment Inventory stations, USGS gage stations, U.S. EPA's Aerometric Information Retrieval System (AIRS) stations, and NOAA weather stations indicated.

clustered near Green Bay. However, there are numerous stations distributed throughout the rest of the basin. Organizations monitoring for fecal coliform in the watersheds include WDNR, USGS-WRD, U.S. EPA, and the U.S. Forest Service (USFS). In addition, two other organizations report through surveys to monitor bacteria in the basin. These include Brown County Land Conservation Department and Brown County Health Department.

Meteorological and Flow Monitoring

USGS maintains 85 gage stations throughout the Fox-Wolf basin to measure flow rates and various other physical characteristics of streams (see Figure 45). Some of these stations have been used for physical and chemical monitoring through the NAWQA program. Gage stations are located on all major rivers and streams in the watershed.

Several organizations also reported that they monitor numerous physical properties in streams in the basin. These include the Brown County Land Conservation Department, WDNR, the Oneida Tribe of Indians, and Green Bay MSD. Paper mills also monitor physical properties through their Industry Rivers Study

Committee. Physical properties measured by all these organizations include stream flow, temperature, pH, dissolved oxygen, biological oxygen demand, chlorophyll, suspended solids, and turbidity.

Three NOAA weather stations are located in the Fox-Wolf basin, and one other station is located just outside the northern boundary of the Wolf watershed. The stations inside the watershed are located within and south of Green Bay in the Lower Fox, and in New London in the southern portion of the Wolf watershed. The station north of the Wolf is located at the Laona Ranger Station in the Nicolet National Forest. These stations measure continuous precipitation data, as well as other meteorological data.
Sediments

There are 97 National Sediment Inventory sites within the Fox-Wolf basin (see Figure 45). The sites are clustered along the Lower Fox, at the inlets and outlets of the "pool" lakes, and along the Red River in the Wolf watershed. Other sites are located more randomly throughout the watersheds in the basin. These sites are administered by the WDNR, USGS-WRD, and U.S. EPA. Some of these sites are involved in cooperative projects between USGS-WRD, WDNR, and Oneida and Menominee Tribes, involving PCB sediment remediation, agricultural BMPs, and trace elements from the Crandon Mine. The Green Bay MSD also reports to conduct some sediment sampling. About 50 of the sites monitor sediment chemistry to assess human health and aquatic life impacts. A total of 48 sites monitor benthic organism tissue, discussed below.

Fish Contaminants, Fish Health, and Aquatic Nuisance Species

As discussed earlier, we have been unable to find specific locational information (i.e. sampling locations) for programs monitoring fish populations or their health. There are statewide programs in existence, but these are discussed in the overall findings discussion. The National Sediment Inventory lists 48 stations that monitor fish tissue to assess the impacts of sediment contamination. These are located throughout the basin, and are administered by WDNR and the U.S. EPA. USGS also maintained NAWQA stations in the basin to examine fish tissue. Two organizations also conduct fish habitat assessments. These include WDNR and the Oneida Tribe of Indians.

A search of the Fish and Wildlife Advisory database on all major Fow-Wolf basin waterbodies revealed fish consumption advisories for nine locations in the basin. Advisories had been issued for six sections of the Fox River, all of the Lake Winnebago "pool" lakes, Shawano Lake, and a section of the Wolf River. In addition, fish advisories have been issued for most of Green Bay. The advisories were all state issued, covered a variety of fish species and related to PCB and mercury levels.

One program was discovered to be monitoring for zebra mussels within the Fox-Wolf basin. The WDNR monitors zebra mussel veligers in the Fox River. Refer to the overall discussion of Lake Michigan monitoring for a discussion about programs that cover multiple tributary watersheds.

Benthos Monitoring

No specific locational information was discovered for state or national programs monitoring benthic organisms. However, several organizations report that they collect macroinvertebrate data (including community composition, and structural and functional integrity) in numerous locations in the basin. These organizations include WDNR (for the Index of Biotic Integrity (IBI)), Brown County Land Conservation Department, Integrated Paper Services, Inc. Other organizations may be monitoring benthic organisms generally in the watershed, among others. These are discussed in the overall discussion of Lake Michigan monitoring (see the NAWQA discussion, for example).

Air Monitoring

Figure 45 illustrates the locations of the 13 air monitoring stations in the basin, according to the U.S. EPA's AIRS database. The stations are distributed evenly throughout the basin. The stations monitor for three of eight indicators in the database, including low-level ozone, particulate matter, and sulfur dioxide.

Wildlife Monitoring

Several organizations are monitoring wildlife in the basin. The Northeast Wisconsin Audubon cunducts an annual bird count; the University of Wisconsin-Green Bay Richer Museum monitors colonial nesting birds; Long Point Bird Observatory monitors breeding marsh birds and amphibians at a couple of sites; and Barkhausen and Green Bay Wildlife Sanctuaries track various bird populations. In addition, there are organizations monitoring wildlife species in the basin on a more regional basis. These are discussed in the overall discussion of Lake Michigan monitoring.

Land Use

The Lower Fox watershed consists of a large portion of urbanized land with relatively few wetlands. Large developments include Green Bay, Appleton, Menasha, Oshkosh, Neenah and Fond du Lac. A substantial portion of the rest of the basin does exist as wetlands. Large wetland areas can be found throughout the Wolf watershed, especially around the headwaters of the Wolf River. The wetlands are not extensively monitored, except in the Wolf headwaters.

Local Assessment

One of the best examples of monitoring data put to beneficial use is "The State of the Bay: A Watershed Perspective" produced by UW-Green Bay's Bud Harris. This very simple, graphicly based format has been an exceptional education tool in a variety of contexts. Dr. Harris is initiating, with Fox/Wolf Basin 2000 assistance, a Strategic Data Acquisition Task Force to help expand monitoring coordination, improve data analysis and guide future activity.

From the perspective of a non-profit watershed alliance (Fox/Wolf Basin 2000), there are several important points to be made with regard to monitoring in the Fox-Wolf basin. First, where data is collected and disseminated, it has been particularly helpful in making the case for enhanced watershed management efforts as well as adding to the understanding of watershed functions and conditions. However, there is likely a large amount of monitoring that was not discovered through this project. Further efforts need to be made to complete the Fox-Wolf basin content in the monitoring database.

When the data collection is not coordinated from a geographic perspective consistently over the years, the ability to effectively manage resources on a watershed basis is lost. Evidence of this is found in this statement taken from the Lake Winnebago Comprehensive Management Plan compiled by the Wisconsin Department of Natural Resources in 1989:

> "There are no current ongoing programs in DNR or other agencies to collect the short- or long-term information necessary to allow adequate assessment of any efforts to reduce nutrient or sediment loading."

Granted, there are some monitoring programs designed to help resource managers, for example the "Single Sites Program" initiated by the WDNR and assisted by USGS. However, according to an observation made by a WDNR employee during a recent Fox-Wolf Basin Strategic Data Acquisition Task Force meeting, WDNR's current "Baseline Monitoring Program" is constrained by U.S. EPA guidelines for data collection in support of Clean Water Act Section 305(b) reports — guidelines that may not be conducive to monitoring to understand ecosystems, evaluate programs or enhance watershed resource management.

Fox-Wolf Basin 2000's own experience in the Pigeon River Watershed (Wolf sub-basin) provides an example. Data collected on the watershed and its impoundment were somewhat scattered among a variety of locations and program files. When brought together, the information was helpful in developing an understanding of the condition of the watershed and the history leading to those conditions. Two data points 20 years apart suggested an annual sedimentation rate in the impoundment near the outlet of the watershed. But because little assessment was done upstream of the impoundment in that time, interpretations of the problem ranged from blaming eroded stream banks to poor farmland management to a golf course upstream to shoreline erosion on the impoundment itself. While those arguments ensued, many citizens responded to additional monitoring efforts by calling for action in the place of monitoring. One recent action, at a cost of about $100,000, was a series of highly visible shoreline stabilization projects that will do little to address the upstream soil and nutrient inputs.

It should also be noted that the information that was derived from the limited data available in the Piegeon River Watershed paralleled some of the "gut" feelings of long-time users or managers of the resource. This suggests anecdotal data and information also needs to be recorded and made accessible. However, this gives rise to another limitation we have encountered – the "quality" of data. The state has a Self-Help Monitoring Program and a Water Action Volunteer Program that encourages citizens to collect basic data (water clarity, phosphorus concentrations and temperature, for example). Efforts to expand such activity have been met with staunch criticism because the data collected would not be reliable and could not meet the rigors of quality assurance and control. Indeed, the uncertainty of anecdotal or non-professionally gathered data have made it easy for those asked to change land use practices or behaviors to question whether they are really the problem.

Another limitation has to do with the measurement of the efficacy of nonpoint source best management practices (BMPs) on a broader (subwatershed or catchment) scale. Much of the research available on BMPs was done in very narrowly defined contexts, which creates a lot of uncertainty when applying pollution reduction efficacy on a broader scale. Little, if any, of the studies look at long term efficiency – how well a practice performs after several years or what kind of maintenance needs and costs can be expected. In addition, literature reviews generally provide a broad range of efficacy estimates. For example, nutrient and sediment reduction rates of 5-90 percent were reported in studies assessing the effectiveness of vegetative filter strips (or buffers). Paired watershed study-designs have been proposed (and implemented in some areas) to address this deficiency. However, they are longer term, a bit unwieldy in garnering adequate participation and quite costly to conduct.

Several observations have been made in the past that there is plenty of data, but little information. The current movement in the Fox-Wolf basin to develop a coordinated monitoring framework is indicative of the inadequate quantity of data, quality of analysis and availability of information necessary to improve watershed management activity.

14. Door County

Background

The study area, Door County, is located in northeast Wisconsin and lies entirely on the Door Peninsula in the Door-Kewaunee watershed. The peninsula is bordered by Lake Michigan on one side and Green Bay on the other. The geology of the peninsula is comprised primarily of dominantly Silurian-aged dolomite. This fractured, calcareous bedrock is easily modified by the dissolution of the bedrock into karst features. These karst features, combined with the relatively thin soil layer found through much of the peninsula, create a high potential for groundwater and surface water contamination.

Status of Watershed Management Efforts in the Study Area

The nature of the geology has been a concern for soil and water conservationists. In particular, these concerns have in large part been at the heart of many of the initiatives and projects of the county's Soil and Water Conservation Department (SWCD). Additionally, the Wisconsin Department of Natural Resources developed a *Water Quality Management Plan* in March of 1995 serving as a guide to water resource activities with a focus on the Door-Kewaunee watershed. Initiatives of the SWCD and the WDNR remain in place as part of a comprehensive watershed management program. These have been the more visible efforts at resource management on the peninsula.

Pollutants of Concern

Aquatic Monitoring

Monitoring coverage for LaMP pollutants reported into the STORET system is shown in Figure 46. As should be obvious from the map, there appears to be no monitoring of LaMP pollutants on the penninsula. In total, there are only 57 water quality monitoring stations in the entire peninsular watershed.

Pollutant Release Monitoring

An examination of Permit Compliance System and Toxic Release Inventory reporting locations in Door County indicates only a few monitoring locations for potential pollution sources throughout the county (see Figure 47). There are now distinct clusters of these locations.

Nutrients and Bacteria

As mentioned previously, there are 57 water quality monitoring stations within the Door-Kewaunee watershed listed in the STORET system. Several others can be found around the peninsula in Green Bay and Lake Michigan. A vast majority of these stations (shown in Figure 46) monitor for some form of nitrogen and phosphorus, the chief nutrients impacting water quality. Thus, where monitoring stations exist, they are likely tracking nitrogen and phosphorus. The stations are distributed fairly evenly across the peninsula. These stations are maintained by WDNR, U.S. EPA, and USGS-WRD. According to our surveys, the Village of Ephraim WWTP monitors phosphorus inputs into Green Bay. The Fish Creek Watershed Study Committee may also be conducting some nutrient tracking along Fish Creek. Additionally, the Door County Sanitation Department monitors ground water for unspecified contamination.

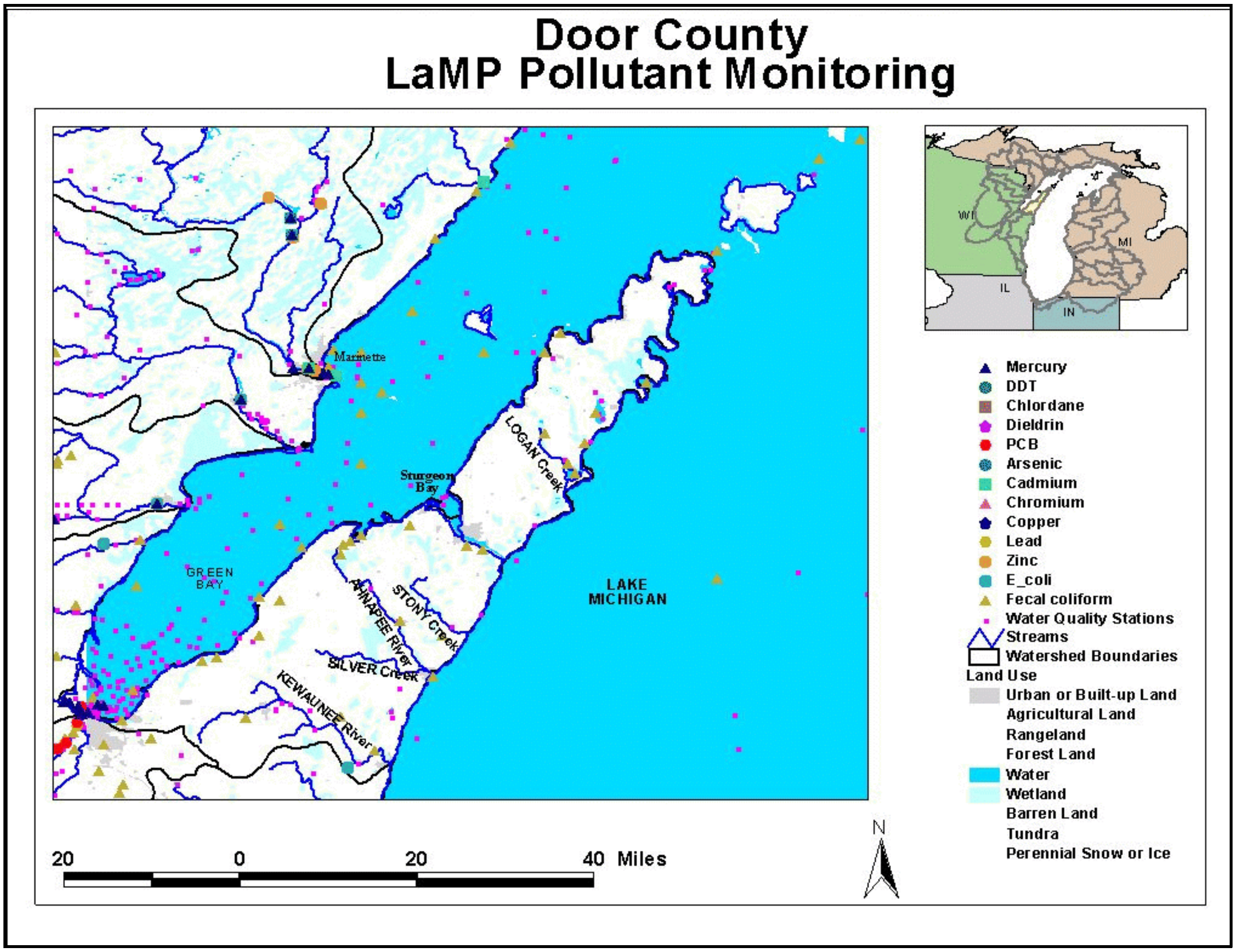

Figure 46. The Door-Kewaunee watershed with ambient water quality and bacteria monitoring stations from U.S. EPA's STORET system displayed by indicators measured.

One station monitors *E. coli* in the watershed on the Kewanee River. The station is maintained by WDNR. Monitoring for fecal coliform is significantly more extensive. About 29 stations can be found throughout the watershed. Most of the stations are located along the shoreline, but there are a number of stations distributed throughout the rest of the peninsula. WDNR maintains all the fecal coliform monitoring stations in the watershed.

Meteorological and Flow Monitoring

USGS maintains five gage stations throughout the Door-Kewaunee watershed to measure flow rates and various other physical characteristics of streams (see Figure 48). All gage stations are located on the Lake Michigan side of the watershed. In addition, the Village of Ephraim WWTP monitors suspended solids near their output into Green Bay.

One NOAA weather station is located on the peninsula. The station is located in Kewaunee at the southeastern corner of the watershed. NOAA stations measure continuous precipitation data, as well as other meteorological data.

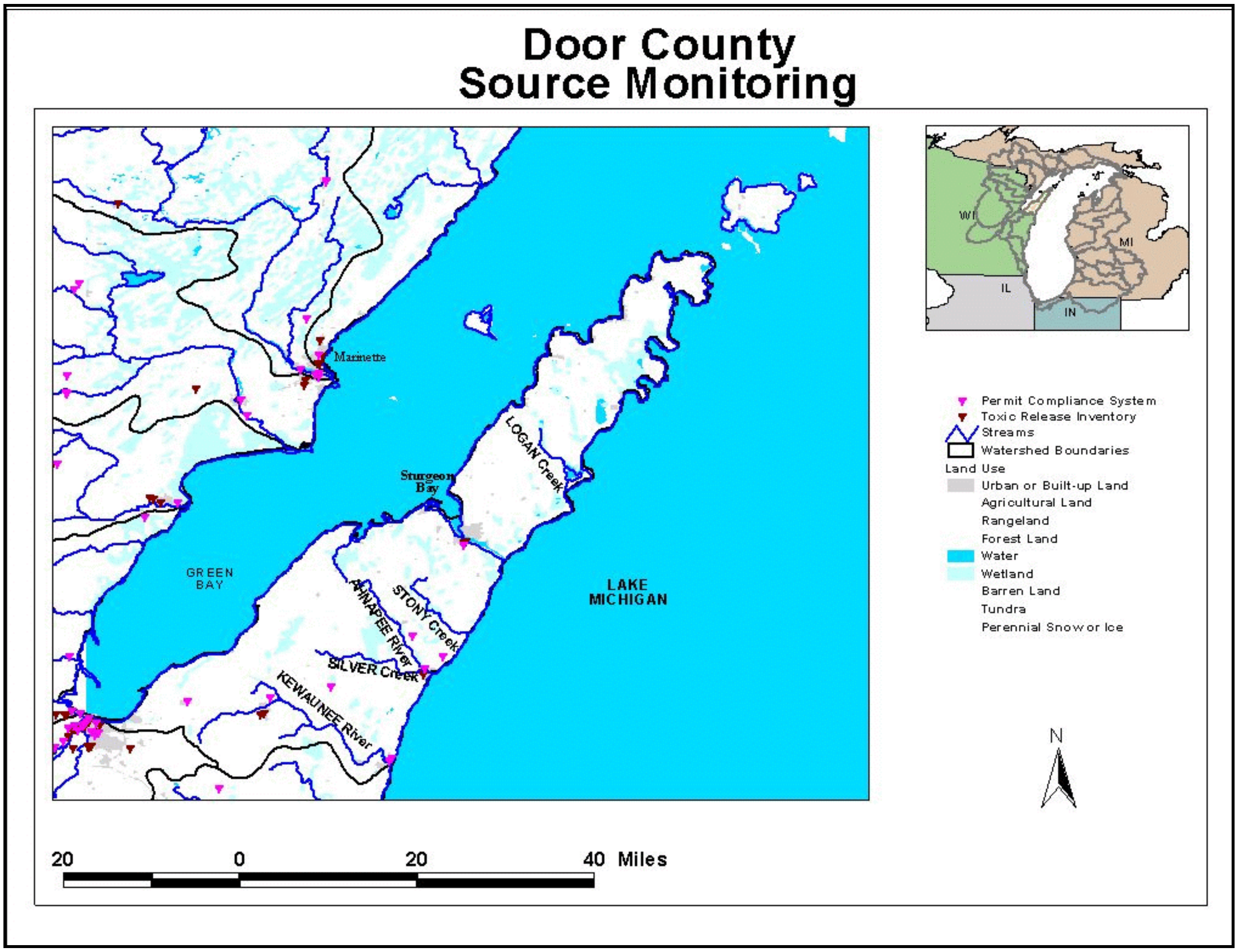

Figure 47. Door-Kewaunee watershed with pollutant sources from the Permit Compliance System and Toxic Release Inventory databases indicated.

Sediments

There are 20 National Sediment Inventory sites within the watershed (see Figure 48). A cluster of sites are located in Sturgeon Bay and the rest are distributed along the shoreline around the peninsula. These sites are all administered by the WDNR. About half of the sites monitor sediment chemistry to assess human health and aquatic life impacts. A total of 11 sites monitor benthic organism tissue, discussed below.

Fish Contaminants, Fish Health, and Aquatic Nuisance Species

As discussed earlier, we have been unable to find specific locational information (such as sampling locations) for programs monitoring fish populations or their health. There are statewide programs in existence, but these are discussed in the overall findings discussion. The National Sediment Inventory lists 11 stations that monitor fish tissue for bottom contamination. These are located throughout the basin, and are administered by the WDNR.

A search of the Fish and Wildlife Advisory database on all major Door County waterbodies revealed fish consumption advisories for two locations in the basin. Advisories had been issued for the Kewaunee River,

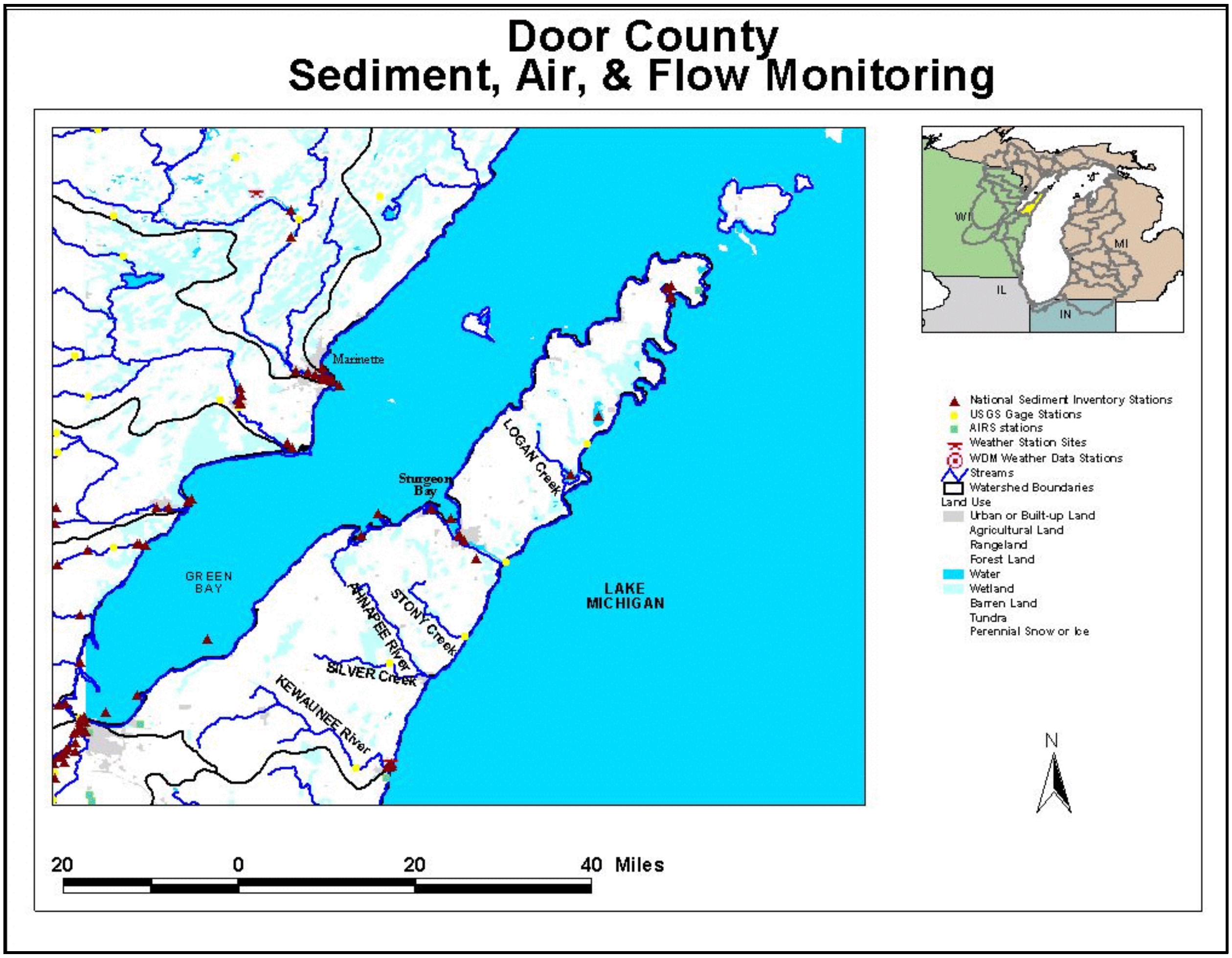

Figure 48. Door-Kewaunee watershed with National Sediment Inventory stations, USGS gage stations, U.S. EPA's Aerometric Information Retrieval System (AIRS) stations, and NOAA weather stations indicated.

and the Ahnapee River. The advisories were all state issued, covered a variety of fish species and related to PCB levels.

No programs were discovered to be monitoring for aquatic nuisance species within the watershed. Refer to the overall discussion of Lake Michigan monitoring for a discussion about programs that cover multiple tributary watersheds.

Benthos Monitoring

No specific locational information was discovered for state or national programs monitoring benthic organisms. Several organizations may be monitoring benthic organisms generally in the watershed, among others. These are discussed in the overall discussion of Lake Michigan monitoring.

Air Monitoring

Figure 48 illustrates the locations of the two air monitoring stations on the peninsula, according to the U.S. EPA's AIRS database. One station is paced at the far western border of the watershed, while the other is on the easternmost tip of the peninsula. Both stations monitor low-level ozone.

Wildlife Monitoring

One private citizen reports to be monitoring wildlife abundance at an unspecified site on the peninsula. There are other organizations monitoring wildlife species generally throughout the Lake Michigan basin. These are discussed in the overall discussion of Lake Michigan monitoring.

Land Use

Many large wetland areas exist across the peninsula. The Lower Fox watershed consists of a large portion of urbanized land with relatively few wetlands. The wetlands are not extensively monitored by water quality stations. The only urbanized development in the watershed is Sturgeon Bay. Most of the watershed consists of agricultural and forest lands.

Local Assessment

Three of the seven area watersheds are designated as Priority Watershed Projects and continue to receive attention through multiple state and local programs designed to reduce water pollution. These programs include nutrient and pest management, soil erosion, and pollution abatement cost-share programs. Door County recently prepared a *Land and Water Resource Management Plan* setting goals and objectives in moving toward improved management of the landscape and protection of water and other natural resources in the county.

The *Water Quality Management Plan* developed for the Door-Kewaunee Basin (1995) identified a number of problem areas and offered a number of recommendations, many of which are in process of implementation. However, a comprehensive area-wide monitoring initiative involving broad collaboration between volunteer organizations and local and state agencies may prove to be a possibility in light of the increasing pressures of development.

Duplication of monitoring efforts does not appear to be an issue, but rather the issue is one of a consistent set of monitoring programs directed toward lakes and streams.

There are several particular areas where attention could be beneficial:

- Improvement in data collection from water quality sampling and well drilling operations, wherein data could be assembled in a form that would allow for qualitative and quantitative analysis on a county-wide basis.

- Creation of additional lake associations, whose members and volunteers could institute regular water monitoring programs. Preliminary work is in process to organize additional lake associations and energize the two that exist to help develop monitoring programs similar to others throughout the state. The Wisconsin Association of Lakes is the reference source for this work.

- The most significant of emerging issues focus on growth and development and the implication toward development pressure from the planned expansion of Highway 42-57. This highway runs from Green Bay to Sturgeon Bay, and is planned for expansion from the current two lane road to a four lane divided highway.

- Collaborative partnerships such as the Door County Stewardship Council offer opportunities to enhance coordination of long-term monitoring programs.

- The Stewardship Council is working to develop coherent strategies that leverage the resources of all local and state agencies and some federal agencies. While we are moving toward cooperative relationships with various organizations, including local governments, a number of people foresee opportunities for coordinated programs that will leverage current standard or routine programs. One missing piece is for the council activities to bridge connections to neighborhood and Lake Associations that would generate an increased interest in watershed protection issues.

19. Findings and Recommendations

The final section of this report centers on general issues that were uncovered throughout the course of research. There are three key areas under which the monitoring inventory provided valuable information and recommendations for improving overall monitoring in the Lake Michigan basin. These include data gaps and unmet needs; underutilized resources; and monitoring coordination and information sharing. Findings are summarized below for these areas, followed by recommendations for improving monitoring infrastructure and use. For reference purposes, sections are labeled with letters and findings and recommendations are numbered.

A. Data Gaps and Unmet Needs

This report, and the inventory on which it is based, represent the first effort to account for the range of environmental monitoring in the Lake Michigan basin. The inventory represents the initial approach toward achieving this ambitious goal. It is a framework on which a more complete inventory will eventually be built.

(1) Finding: There are several gaps in the inventory that are listed below and throughout the report. While some of these gaps are areas that have not been well covered in the inventory, others may represent gaps in the monitoring coverage. At this point, it is difficult to tell which are gaps in the monitoring inventory and which are actual monitoring gaps. Further improvement of the inventory database is needed to better clarify this distinction.

(1.1) Recommendation: *Continue to update the inventory and expand data collection to include all tributaries.* Fourteen tributaries were covered extensively in this project. The update should carry out the same research process with the other tributary watersheds in the basin.

(2) Finding: There are several key monitoring areas where little information was received, but where more monitoring is believed to exist. These areas include monitoring for *E. coli*, fish population characteristics, aquatic nuisance species, benthic organisms, wildlife, and habitat. We received some information about *E. coli* monitoring from county health departments and other local agencies, but believe more local agencies conduct such monitoring. For the other areas, we have some evidence to believe that state Departments of Natural Resources and federal agencies such as the U.S. Fish and Wildlife Service, U.S. Forest Service, and U.S. Department of Agriculture conduct monitoring programs in these areas. We received limited information about efforts made in specific watersheds by these agencies, but most of this information came from indirect sources. It is important that these agencies supply more complete information on their monitoring efforts to improve the overall completeness inventory.

(2.1) Recommendation: *Establish better lines of communication with state DNRs, USFWS, USFS, and USDA.* Further work needs to be carried out in order to obtain information from these agencies on their monitoring programs. This will fill in some of the major gaps in the inventory database.

(2.2) Recommendation: *Better integrate habitat and wildlife monitoring with traditional water quality monitoring.* One of the most difficult tasks needed to complete the monitoring inventory was to convince natural resource agencies that wildlife and habitat monitoring should be included in the inventory along with more traditional water quality monitoring. Agencies conducting monitoring in these areas must develop a better understanding of how all monitoring information can fit together so that policy makers, residents, and other stakeholders have access to a complete database of environmental monitoring information.

(3) Finding: Another result of this initial approach to the monitoring inventory for the Lake Michigan basin was that much of the information included only general information about the geographic location of monitoring sites. Many organizations reported monitoring for parameters across a broad geographic area but did not include specific site references. Locational information is critical if the inventory is to be brought online in a geographically-searchable format.

(3.1) Recommendation: *Improve information on the geographic location of monitoring sites.* This is especially true for monitoring programs at the local level. This will require extensive follow-up communication with those who originally reported into the inventory database.

(4) Finding: A further gap in the monitoring information obtained for this report, was the lack of complete and continuing coverage of Lake Michigan Mass Balance data. The Mass Balance project was a first of its kind sampling event designed to collect data across several variables in a coordinated fashion. The information produced by a project of this magnitude is valuable throughout the monitoring community. However, a project as large and complex as the Mass Balance project requires substantial time to collect, verify, validate, integrate, analyze, and report on the data. At the time the research for this report was conducted, most of the data from the Mass Balance project was not readily available for public consumption. Therefore, information contained in this report on sampling within the Lake Michigan Mass Balance project is incomplete and limited mostly to sampling location and general sampling focus. The data collected for the project has been quality assured, and, when released, will be more detailed. When these results are released, they will be added to the online version of the inventory database. Additionally, the value of coordinated sampling data (as collected in the Mass Balance project) would be greatly enhanced by a repeat of the sampling event ten years following completion of the original sampling.

(4.1) Recommendation: *Initiate planning for a coordinated sampling event for ten years following the initial Mass Balance project, and share data and modeling results with the public in a timely fashion through numerous outlets.*

(5) Finding: This initial project specifically avoided attempting to collect information about university monitoring projects. There were two reasons for this. First, much academic research is conducted in one-time, short-term projects, and therefore does not meet the need for baseline information and ongoing monitoring. Second, universities are complex environments with numerous independent research projects being conducted across each campus. However, some academic institutions conduct a number of important ongoing, long-term projects, and information on these projects should be included in the inventory. Sea Grant programs and other institutes catalog the university work they fund. Closer ties need to be established with these programs and such efforts need to be expanded throughout the basin.

(5.1) Recommendation: *Include academic research and data collection efforts in future updates to the monitoring inventory.*

(6) Finding: While a number of LaMP pollutants, such as mercury and copper, are monitored extensively across the basin, it has been difficult to find monitoring information on some of the other pollutants. These under-monitored pollutants include all the emerging LaMP pollutants, along with DDT, HCBs, toxaphene, and PAHs. The need for monitoring of these pollutants should be clarified.

(6.1) Recommendation: *Further examine the monitoring coverage of specific LaMP critical pollutants and emerging pollutants.*

B. Underutilized Resources

Along with the gaps in monitoring coverage identified in this project, some resources in the basin were also discovered that do not appear to be fully utilized. Monitoring is an area of environmental management that has often been underfunded in the past. Therefore, in order to achieve the most complete monitoring coverage possible, one must take advantage of all available resources. If resources, such as monitoring personnel, go unutilized, then some aspects of a complete monitoring coverage must be sacrificed. To avoid such a sacrifice, creative methods must be used to combine these underutilized resources with other monitoring programs.

(1) Finding: One of these underutilized resources is volunteer groups. These groups represent a vast pool of potential data collection personnel. Most of the volunteer groups currently engage in some form of monitoring, but often their efforts are not incorporated into state or regional monitoring plans, and the information collected is only reported internally or locally. These volunteers need to be better enabled to contribute to regional monitoring efforts. The challenge lies in preparing volunteers to collect environmental information in such a way that it is both accurate and relevant to regional needs, and of sufficient quality to be useful for resource managers and policy makers.

(1.1) Recommendation: *Take better advantage of relatively untapped volunteer monitoring resources.*

(2) Finding: Another group that is underutilized is local agencies. Examples of such agencies are health departments, conservation districts, and planning agencies. In many cases, these agencies are already engaged in monitoring to serve their local needs. Most of the agencies employ professionals trained to accurately monitor environmental parameters. These groups were discovered sporadically in the process of constructing the monitoring inventory. Several health departments reported monitoring of surface and ground waters for *E. coli*, coliform, and other contaminants of special interest to public health officials. Conservation districts may individually be monitoring for a number of parameters related to nonpoint source pollution, general water quality, or other issues. Planning agencies or commissions track population, mass transportation status and other land use characteristics for planning and funding purposes. It is likely that other similar agencies are also conducting monitoring programs. Information on these programs needs to be incorporated into the inventory. Also, there is an opportunity to link these agencies into basinwide monitoring efforts.

(2.1) Recommendation: *Take better advantage of local agencies such as health departments, conservation districts and planning agencies.*

(3) Finding: To best capitalize on these underutilized resources, it is important that these local groups (both volunteer groups and local agencies) be linked into basinwide efforts, but at the same time retain their local focus and discretion. Much of the energy that maintains these groups arises from a focus on local problems. While this is important, the value of their data to the larger basin is often overlooked. Linkages need to be made between local groups throughout the basin. However, such a basinwide focus needs to incorporate local data collectors in a way that is locally-driven.

(3.1) Recommendation: *Establish a better framework for bottom-up monitoring program linkages.*

(4) Finding: Part of the difficulty in using data collected at the local level is that there are few standards at the basinwide level to knit the data together. The local focus of the data collection effort often will leave the data incompatible with other data from neighboring localities. In order to use locally-driven data, the aspects of the collection and reporting processes need to be standardized across the basin. This standardization will make local monitoring results more widely usable and allow for aggregation and analysis across the basin as a whole.

(4.1) Recommendation: *Standardize data collection and reporting*.

C. Monitoring Coordination and Information Sharing

The final issue area does not involve direct monitoring, but responds to the need to coordinate monitoring efforts. As should be obvious from this report, there are a wide array of organizations involved in monitoring at the federal, state and local levels. However, no single organization is responsible for planning, coordinating, or disseminating monitoring efforts for the entire Lake Michigan basin. In the absence of a single organization, a council of organizations has formed to take on this task — the Lake Michigan Monitoring Coordination Council. The council's task — to coordinate monitoring efforts for basinwide goals — is a difficult one. However, several steps could be taken to improve the prospects of this coordination.

(1) Finding: A major coordination problem is the lack of a central source for monitoring information. The inventory that this report evaluates is the first step toward creating such a central source. However, this one-time inventory is currently not universally accessible and may quickly become dated if the database is not continually updated by monitoring organizations in the basin. Therefore, these monitoring organizations need to be encouraged to report on their monitoring projects continually into a universally-accessible database. This database should contain proper metadata about the monitoring program and the data that is reported. Eventually, this database should directly link to monitoring data, wherever possible. The database should be developed for the Internet and allow for the metadata to be searched geographically and by metadata content.

(1.1) Recommendation: *Encourage state, federal, tribal, and local agencies to report monitoring coverage and results to a meta-database with universal access.*

(1.2) Recommendation: *Develop an online database of monitoring information that is geographically-based, and content-searchable.*

(2) Finding: Beyond creating and reporting to a shared database of monitoring program information, it would be most effective to link monitoring programs into a coordinated network. As it is, organizations make most, if not all, decisions about their monitoring programs based on goals for their local coverage area. Rarely does this area cover the entire Lake Michigan basin. Without a coordinated network, basinwide goals may go unmet. Several actions must be taken to make sure this network can successfully address basinwide goals. First, the network must contain all the necessary components for complete coverage. This means that common indicators need to be agreed upon for the basin, and all organizations monitoring for indicator data need to be included in the network. State of the Lake Ecosystem Conference (SOLEC) and LaMP indicators have already been established and should be adapted or condensed for use in the network. After this, a set of standard methods should be established for monitoring the agreed upon indicators within the basin. Standard methods will ensure that data is comparable and able to be combined for analysis across the basin.

(2.1) Recommendation: *Develop and coordinate the implementation of comparable methods to collect indicator data in a coordinated network.*

Appendix A.

Acronyms and Glossary

AOC	Area of Concern
AIRS	U.S. EPA's Aerometric Information Retrieval System
BMP	Best Management Practice
BSFWD	Bureau of Sport Fisheries and Wildlife Data
CLMP	Cooperative Lakes Management Program
COE	U.S. Army Corps of Engineers
EPRI	Electric Power Research Institute
GLC	Great Lakes Commission
GLFC	Great Lakes Fishery Commission
GLNPO	Great Lakes National Program Office
GLERL	Great Lakes Environmental Research Laboratory
IDEM	Indiana Department of Environmental Management
IEPA	Illinois Environmental Protection Agency
IJC	International Joint Commission
LMMCC	Lake Michigan Monitoring Coordination Council
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
MMSD	Milwaukee Metropolitan Sewage District
MSD	Metropolitan Sanitary District or Metropolitan Sewage District
NCDC	National Climatic Data Center
NIPC	Northeast Illinois Planning Commission
RAP	Remedial Action Plan
SLIC	Sea Lamprey Integration Committee
TMDL	Total Maximum Daily Load
U.S. EPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service

USGS-WRD	U.S. Geological Survey – Water Resources Division
WAV	Water Action Volunteers
WDNR	Wisconsin Department of Natural Resources
WWTP	Waste-water treatment plant

Appendix B.

Lake Michigan Tributary Monitoring Project Participants

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Appendix C.

Lake Michigan Monitoring Inventory Form

Following is the form that was distributed to organizations thought to be possibly conducting monitoring programs. The form was slightly tailored for use in local areas. A web-based form was also developed to enhance return rates. This form can currently be found at: http://www.glc.org/projects/lamps/monitor.html.

Lake Michigan Monitoring Inventory Form

The following form is intended to provide us with an inventory of federal and state agency monitoring programs in the Lake Michigan Basin. Please complete this form to the best of your ability, indicating the monitoring efforts that your agency currently undertakes, and return it to us as soon as possible. If you conduct more than one monitoring effort, please copy and complete a separate form for each program. This should take less than 20 minutes to complete.

General Information

The questions below will provide us with important background on your organization and monitoring efforts and may eventually result in greater use of your monitoring results.

1) Please provide your primary contact information.

Name: ____________________

Organization: ____________________

Address: ____________________

City: ____________________ State: _____ Zip Code: __________

Phone: ____________________ Fax: ____________________

E-mail: ____________________ Website: ____________________

Watersheds covered: ____________________

____

2) Who is the manager for the monitoring program?

____

3) Briefly describe the overall purpose or goal of the monitoring/information collection effort.

____

____

4) Approximately, when did the monitoring program begin? (month / year) ______/______

Monitoring Information

The following questions ask about specific details of your monitoring program. They will help us understand what is being done in your area to monitor the health of the ecosystem.

5) As specifically as possible, please describe the boundary of the location or geographic scope of your monitoring effort (e.g., named or numbered river reach, watershed, county or township boundary, latitude/longitude). Please include as much descriptive information as possible.

____

____

6) Medium being monitored:

❑ Water ❑ Land ❑ Air ❑ Soil ❑ Biota/Wildlife ❑ Other (specify: ____________)

7) Please select the category that best fits the type of information being collected.

- ❑ Chemical (e.g. pH, BOD, mercury, phosphorus, PCBs)
- ❑ Microbiological (e.g. bacteria or other microbial organisms)
- ❑ Fish or aquatic invertebrates
- ❑ Other wildlife (e.g. turtles, beavers, deer, etc)
- ❑ Physical characteristics (e.g. hydrology, habitat, geology, soil, vegetation, forests, wetlands)
- ❑ Land uses (e.g. urbanized, agricultural, residential, industrial, brownfields sites)
- ❑ Other (specify: ____________________ ____________________)

8) Do you collect data on any of the following? ❑ PCBs ❑ Dieldrin ❑ Chlordane

❑ DDT	❑ Lead	❑ Zinc	❑ Cyanide	❑ PAHs	❑ None of the above
❑ Mercury	❑ Cadmium	❑ Chromium	❑ Hexachlorobenzene	❑ Atrazine	
❑ Dioxins/Furans	❑ Copper	❑ Arsenic	❑ Toxaphene	❑ Selenium	

9) Please give a specific description of any other information being collected (i.e. list specific indicators measured).

____

____

10) How often is the information collected?

❑ Daily ❑ Weekly ❑ Monthly ❑ Semiannually ❑ Annually ❑ Other (specify: ____________)

Program Information

We need some final information about your monitoring program so that we can assess the extent and needs for monitoring funding and training.

11) Please list the name or type of any standardized methodology used (e.g. EPA guidelines, standard methods texts, or kit procedures).

____

12) Please list any standardized quality assurance or quality control procedures that are followed.

____

____

13) Select the classification that best describes the individuals who collect monitoring data.

❑ Paid staff ❑ Volunteers ❑ Students ❑ Other (specify: ______________________)

14) How many staff or volunteers participate in the monitoring project, on average? ____________

15) Was training provided to data gatherers? ❑ Yes ❑ No

16) If yes, who provided the training? ______________________________

17) Where is the monitoring data reported and stored (e.g., which office or agency)?

____

18) Which format is used to store the data (i.e., which electronic format or software is used, or is it stored in a hard copy format)?

____

19) Is the data stored indefinitely? ❑ Yes ❑ No

20) If no, how long is the information stored? ______________________________

21) How is the monitoring data ultimately used (e.g. in Remedial Action Plans, educational materials, research, watershed planning, regulatory compliance)?

____

____

22) (Optional) Please list the approximate annual budget for the monitoring effort. $____________.00

23) Is this funding ongoing and reliable? ❑ Yes ❑ No

24) Please list any other parameters that you would like to monitor or other areas that you feel need additional monitoring in your region.

____

____

25) Please provide us with any other relevant information that you think would give us a more complete understanding of your monitoring efforts. Feel free to append any additional documentation that you think would be helpful.

____

____

____

Thank you for your assistance.
Your input will help us better determine the scope and need for monitoring efforts in the Lake Michigan basin.

When completed, please return this form by mail or fax, to:

Ric Lawson
Great Lakes Commission
400 Fourth Street
Ann Arbor, MI 48103
Fax: (734) 665-4370

Attachment 3

Cost Estimate for Long-term Monitoring

Table C.1 - MNR Costs for Sampling (One Event/ 5 Yrs) - Long-Term Monitoring Plan Lower Fox River/Green Bay

Task 100 - Surface Water Sampling (30 days, 4 people)
Task 200 - Surface Sediment Sampling (2 weeks, 4 people)
Task 300 - Fish and Invertebrate Tissue Sampling (8 weeks,3 people - J.Amrhein) (also for Institutional Controls)
Task 400 - Mallard duck, Bald Eagle and Cormorant Bird Tissue Sampling (4 weeks, 4 people)
Task 500 - Mink Habitat Chacterization (one month, 2 people)
Task 600 - Data Analysis

LABOR/PERSONNEL (HOURS)	Task 100	Task 200	Task 300	Task 400	Task 500	Task 600	Hours	Rate	Cost
Director E12	10	10	10	10	10	20	70	$125	$8,750
Sr.Tech Manager E11	50	50	50	50	50	20	270	$110	$29,700
Tech Manager E10	50	50	50	50	50	80	330	$98	$32,340
Project E8	350	120	350	180	180	80	1260	$75	$94,500
Senior Staff E7	350	120	350	180	180	300	1480	$62	$91,760
Staff Scientist E6	350	120	350	180	180	300	1480	$52	$76,960
Scientist1 E5	350	120	350	180	180	120	1300	$45	$58,500
P.A./Technician E4	150	50	160	80	80	80	600	$50	$30,000
Drafter E2	150	50	160	80	80	150	670	$38	$25,460
Word Processing E1	150	50	160	80	80	150	670	$40	$26,800
Labor Subtotal	$112,750	$46,130	$114,030	$64,010	$64,010	$73,840		Labor Subtotal:	$474,770

DIRECT COSTS	Task 100	Task 200	Task 300	Task 400	Task 500	Task 600			Cost
Travel/per diem	$5,000	$5,000	$5,000	$5,000	$5,000	$0			$25,000
Supplies/Phone/Repro	$7,000	$7,000	$7,000	$7,000	$20,000	$30,000			$78,000
Equipment	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000			$60,000
Sampling vessel	$30,000	$20,000	$30,000	$30,000	$10,000	$0			$120,000
Other	$5,000	$5,000	$5,000	$5,000	$5,000	$30,000			$55,000
Location control	$2,000	$2,000	$2,000	$2,000	$2,000	$0			$10,000
Direct Costs Subtotal	$59,000	$49,000	$59,000	$59,000	$52,000	$70,000		Direct Subtotal:	$348,000
								(add 8% to subs):	$0
Task Total	$171,750	$95,130	$173,030	$123,010	$116,010			Total:	$822,770

ANALYTICAL COSTS (No. of samples)	Task 100	Task 200	Task 300	Task 400	Task 500	Sum	Unit Cost	Total
PCB congeners	260	100	900	460	0	1720	$900	$1,548,000
mercury	260	100	900	460	0	1720	$200	$344,000
%lipids	0	0	450	230	0	680	$50	$34,000
TOC	260	100	0	0	0	360	$30	$10,800
Grain Size	0	100	0	0	0	100	$150	$15,000
DDE	0	0	550	440	0	990	$150	$148,500
Conventionals	260	100	0	0	0	360	$100	$36,000
Analytical Subtotal	$319,800	$138,000	$1,095,000	$583,500	$0			$2,136,300
Task Total (for 5 years)	$491,550	$233,130	$1,268,030	$706,510	$116,010		**5 YR TOTAL:**	**$2,959,070**
							Cost per year:	**$591,814**

Notes:

1) Assume 550 fish samples for human health,250 fish for environment, 100 mussels

2) Assume 320 duck samples, 120 DCC samples, and 20 eagle samples

3) Conduct this sampling event once every five years

4) PCB congener analysis cost estimate from Triangle Lab ($500) and J. Amhrein of WDNR ($900)

Table C.2 - Estimated Costs for CDF or CAD Sampling (Per Year) - Lower Fox River/Green Bay

Task 100 - CDF Groundwater Monitoring (3 events/year, 6 wells/ CDF, 6 CDF, 3 people - 108 days at 10hr/day)
Task 200 - CDF Surface Water Sampling (2 events/year, 1 station/CDF, 6 CDF, 2 people)
Task 300 - CDF Surface Sediment Sampling (1 event/year, 5 to 10 stations/CDF, 4 people)
Task 400 - CDF Seep Sampling (same as above)
Task 500 - Data Analysis

LABOR/PERSONNEL (HOURS)	Task 100	Task 200	Task 300	Task 400	Task 500	Hours	Rate	Cost
Director E12	5	5	5	5	5	25	$125	$3,125
Sr.Tech Manager E11	10	10	10	10	10	50	$110	$5,500
Tech Manager E10	20	20	20	20	20	100	$98	$9,800
Project E8	1080	80	80	80	70	1390	$75	$104,250
Senior Staff E7	1080	80	80	80	70	1390	$62	$86,180
Staff Scientist E6	1080	30	80	80	120	1390	$52	$72,280
Scientist1 E5	100	30	80	80	120	410	$45	$18,450
P.A./Technician E4	80	5	5	5	40	135	$50	$6,750
Drafter E2	80	5	5	5	40	135	$38	$5,130
Word Processing E1	80	5	5	5	40	135	$40	$5,400
Labor Subtotal	$222,545	$18,195	$23,045	$23,045	$30,035		Labor Subtotal:	$316,865
DIRECT COSTS								
Travel/per diem	$5,000	$1,000	$1,000	$1,000	$0			$8,000
Supplies/Phone/Repro	$2,000	$2,000	$2,000	$2,000	$5,000			$13,000
Equipment	$5,000	$5,000	$5,000	$5,000	$10,000			$30,000
Sampling vessel	$5,000	$10,000	$10,000	$10,000	$0			$35,000
Other	$5,000	$5,000	$5,000	$5,000	$5,000			$25,000
Location control	$1,000	$1,000	$1,000	$1,000	$0			$4,000
Direct Costs Subtotal	$23,000	$24,000	$24,000	$24,000	$20,000		Direct Subtotal:	$115,000
							(add 8% to subs):	$0
Task Total	$245,545	$42,195	$47,045	$47,045	$50,035		Total:	$431,865
ANALYTICAL COSTS	**No. of samples**					**Sum**	**Unit Cost**	**Total**
PCB congeners	110	15	15	10	6	156	$900	$140,400
mercury	110	15	15	10	6	156	$200	$31,200
% lipids	0	0	0	0	0	0	$50	$0
TOC	110	15	15	10	6	156	$30	$4,680
Grain Size	0	0	15	0	6	21	$150	$3,150
DDE	110	15	15	10	6	156	$150	$23,400
Conventionals	110	15	15	10	6	156	$100	$15,600
Analytical Subtotal	$151,800	$20,700	$22,950	$13,800	$9,180			$218,430
Task Total (for 5 years)	$397,345	$62,895	$69,995	$60,845	$59,215		**TOTAL:**	**$650,295**
							Cost per year:	**$650,295**

Notes:
1) All values are ballpark estimates
2) Costs do not include monitoring well installations
3) Conduct this sampling event every year for the first 5 years, but frequency may diminish over the years
4) PCB congener analysis cost estimate from Triangle Lab ($500) and J. Amhrein of WDNR ($900)

Table C.3 - Estimated Costs for *In Situ* Cap Sampling (Per Year) - Lower Fox River/Green Bay

Task 100 - Visual Assessments (bathymetry, camera surveys) (1 event/year, 2 people, 1 week)
Task 200 - Surface Water Sampling (2 event/year, 1 station/cap, 2 people)
Task 300 - Surface Sediment and PoreWater Sampling (1 event/year, 5 to 10 stations/cap, 4 people)
Task 400 - Sediment Cores through CAP (1 event/year, 5 to 10 stations/cap, 4 people)
Task 500 - Data Analysis

LABOR/PERSONNEL (HOURS)	Task 100	Task 200	Task 300	Task 400	Task 500	Hours	Rate	Cost	
Director E12	5	5	5	5	5	25	$125	$3,125	
Sr.Tech Manager E11	10	10	10	10	10	50	$110	$5,500	
Tech Manager E10	20	20	20	20	20	100	$98	$9,800	
Project E8	40	80	80	80	70	350	$75	$26,250	
Senior Staff E7	100	80	80	120	150	530	$62	$32,860	
Staff Scientist E6	100	30	80	120	150	480	$52	$24,960	
Scientist1 E5	20	30	80	120	120	370	$45	$16,650	
P.A./Technician E4	5	5	5	5	40	60	$50	$3,000	
Drafter E2	5	5	5	5	40	60	$38	$2,280	
Word Processing E1	5	5	5	5	40	60	$40	$2,400	
Labor Subtotal	$19,625	$18,195	$23,045	$29,405	$36,555		Labor Subtotal:	$126,825	
DIRECT COSTS									
Travel/per diem	$1,000	$1,000	$1,000	$1,000	$0			$4,000	
Supplies/Phone/Repro	$2,000	$2,000	$2,000	$2,000	$10,000			$18,000	
Equipment	$15,000	$5,000	$5,000	$5,000	$10,000			$40,000	
Sampling vessel	$10,000	$10,000	$10,000	$10,000	$0			$40,000	
Other	$5,000	$5,000	$5,000	$5,000	$10,000			$30,000	
Location control	$1,000	$1,000	$1,000	$1,000	$0			$4,000	
Direct Costs Subtotal	$34,000	$24,000	$24,000	$24,000	$30,000		Direct Subtotal:	$136,000	$136,000
							(add 8% to subs):	$0	
Task Total	$53,625	$42,195	$47,045	$53,405	$66,555		Total:	$262,825	$262,825
ANALYTICAL COSTS	No. of samples					Sum	Unit Cost	Total	
PCB congeners		6	45	50		101	$900	$90,900	
mercury		6	45	50		101	$200	$20,200	
% lipids		0	0	0		0	$50	$0	
TOC		6	45	50		101	$30	$3,030	
Grain Size		0	45	0		45	$150	$6,750	
DDE		6	45	50		101	$150	$15,150	
Conventionals		6	45	50		101	$100	$10,100	
Analytical Subtotal	$0	$8,280	$68,850	$69,000	$0			$146,130	$146,130
Task Total (for 5 years)	$53,625	$50,475	$115,895	$122,405	$66,555		**TOTAL:**	**$408,955**	$408,955
							Cost per year:	**$408,955**	

Notes:

1) All values are ballpark estimates

2) Costs do not include monitoring well installations

3) Conduct this sampling event every year for the first 5 years, but frequency may diminish over the years

4) PCB congener analysis cost estimate from Triangle Lab ($500) and J. Amhrein of WDNR ($900)

Table C.4 - Estimated Costs for Institutional Controls and No Action Alternatives (Per Year)

Maintain fish consumption advisories and deed restrictions (No Action and Institutional controls)

Task 100 - Deed restrictions
Task 200 - NA
Task 300 - Fish and Invertebrate Tissue Sampling (8 weeks,3 people - J.Amrhein) (also for Institutional Controls)
Task 400 - Data Analysis
Task 500 - NA

LABOR/PERSONNEL (HOURS)	Task 100	Task 200	Task 300	Task 400	Task 500	Hours	Rate	Cost
Director E12	10		20	20		50	$125	$6,250
Sr.Tech Manager E11	10		60	50		120	$110	$13,200
Tech Manager E10	20		60	50		130	$98	$12,740
Senior Project E9						0	$87	$0
Project E8	100		400	200		700	$75	$52,500
Senior Staff E7	100		400	200		700	$62	$43,400
Staff Scientist E6	100		400	200		700	$52	$36,400
Scientist1 E5			400	200		600	$45	$27,000
P.A./Technician E4	20		200	200		420	$50	$21,000
Drafter E2	20		200	100		320	$38	$12,160
Word Processing E1	10		200	100		310	$40	$12,400
Labor Subtotal	$26,370	$0	$134,180	$77,500	$0	Labor Subtotal:		$238,050
DIRECT COSTS								
Travel/per diem	$0	$0	$5,000	$0	$0			$5,000
Supplies/Phone/Repro	$0	$0	$7,000	$0	$0			$7,000
Equipment	$20,000	$0	$10,000	$10,000	$0			$40,000
Sampling vessel	$0	$0	$20,000	$0	$0			$20,000
Other	$10,000	$0	$5,000	$20,000	$0			$35,000
Location control	$0	$0	$2,000	$0	$0			$2,000
Direct Costs Subtotal	$30,000	$0	$49,000	$30,000	$0	Direct Subtotal:		$109,000
						(add 8% to subs):		$0
Task Total	$56,370	$0	$183,180	$107,500	$0	Total:		$347,050
ANALYTICAL COSTS	No. of samples					Sum	Unit Cost	Total
PCB congeners	0	0	900	0	0	900	$900	$810,000
mercury	0	0	900	0	0	900	$200	$180,000
%lipids	0	0	450	0	0	450	$50	$22,500
TOC	0	0	0	0	0	0	$30	$0
Grain Size	0	0	0	0	0	0	$150	$0
DDE	0	0	550	0	0	550	$150	$82,500
Conventionals	0	0	0	0	0	0	$100	$0
Analytical Subtotal	$0	$0	$1,095,000	$0	$0			$1,095,000
Task Total (for 5 years)	$56,370	$0	$1,278,180	$107,500	$0		**TOTAL:**	**$1,442,050**
							Cost per year:	**$288,410**

Notes:
1) Assume 550 fish samples for human health,250 fish for environment, 100 mussels
3) Conduct this sampling event once every five years
4) PCB congener analysis cost estimate from Triangle Lab ($500) and J. Amhrein of WDNR ($900)

Table C.5 - Estimated Costs for No Action (Per Year)

Maintain fish consumption advisories and deed restrictions (No Action and Institutional controls)

Task 100 - Deed restrictions
Task 200 - NA
Task 300 - Fish and Invertebrate Tissue Sampling (8 weeks,3 people - J.Amrhein) (also for Institutional Controls)
Task 400 - Data Analysis
Task 500 - NA

LABOR/PERSONNEL (HOURS)	Task 100	Task 200	Task 300	Task 400	Task 500	Hours	Rate	Cost
Director E12	10		20	20		50	$125	$6,250
Sr.Tech Manager E11	10		60	50		120	$110	$13,200
Tech Manager E10	20		60	50		130	$98	$12,740
Senior Project E9						0	$87	$0
Project E8	100		400	200		700	$75	$52,500
Senior Staff E7	100		400	200		700	$62	$43,400
Staff Scientist E6	100		400	200		700	$52	$36,400
Scientist1 E5			400	200		600	$45	$27,000
P.A./Technician E4	20		200	200		420	$50	$21,000
Drafter E2	20		200	100		320	$38	$12,160
Word Processing E1	10		200	100		310	$40	$12,400
Labor Subtotal	$26,370	$0	$134,180	$77,500	$0	Labor Subtotal:		$238,050
DIRECT COSTS								
Travel/per diem	$0	$0	$5,000	$0	$0			$5,000
Supplies/Phone/Repro	$0	$0	$7,000	$0	$0			$7,000
Equipment	$20,000	$0	$10,000	$10,000	$0			$40,000
Sampling vessel	$0	$0	$20,000	$0	$0			$20,000
Other	$10,000	$0	$5,000	$20,000	$0			$35,000
Location control	$0	$0	$2,000	$0	$0			$2,000
Direct Costs Subtotal	$30,000	$0	$49,000	$30,000	$0	Direct Subtotal:		$109,000
						(add 8% to subs):		$0
Task Total	$56,370	$0	$183,180	$107,500	$0		Total:	$347,050

ANALYTICAL COSTS	No. of samples					Sum	Unit Cost	Total
PCB congeners	0	0	900	0	0	900	$900	$810,000
mercury	0	0	900	0	0	900	$200	$180,000
%lipids	0	0	450	0	0	450	$50	$22,500
TOC	0	0	0	0	0	0	$30	$0
Grain Size	0	0	0	0	0	0	$150	$0
DDE	0	0	550	0	0	550	$150	$82,500
Conventionals	0	0	0	0	0	0	$100	$0
Analytical Subtotal	$0	$0	$1,095,000	$0	$0			$1,095,000
Task Total (for 5 years)	$56,370	$0	$1,278,180	$107,500	$0		**TOTAL:**	**$1,442,050**
							Cost per year:	**$288,410**

Notes:
1) Assume 550 fish samples for human health,250 fish for environment, 100 mussels
3) Conduct this sampling event once every five years
4) PCB congener analysis cost estimate from Triangle Lab ($500) and J. Amhrein of WDNR ($900)

Table C.6 - Sampling Costs During Dredging Per Alternative (Assume 5 years duration)

Task 100 - Surface Water Sampling (30 days, 4 people)
Task 200 - Caged Tissue Sampling
Task 300 - Surface Sediment Sampling
Task 400 - Data Analysis
Task 500 - NA

LABOR/PERSONNEL (HOURS)	Task 100	Task 200	Task 300	Task 400	Task 500	Hours	Rate	Cost	
Director E12	5	5	5	5		20	$125	$2,500	
Sr.Tech Manager E11	50	50	50	50		200	$110	$22,000	
Tech Manager E10	50	50	50	50		200	$98	$19,600	
Senior Project E9				0		0	$87	$0	
Project E8	500	100	400	160		1160	$75	$87,000	
Senior Staff E7	500	100	400	160		1160	$62	$71,920	
Staff Scientist E6	500	100	400	160		1160	$52	$60,320	
Scientist1 E5	500	100	400	160		1160	$45	$52,200	
P.A./Technician E4	200	50	160	80		490	$50	$24,500	
Senior Drafter E3				0		0	$50	$0	
Drafter E2	200	50	160	80		490	$38	$18,620	
Word Processing E1	200	50	160	80		490	$40	$19,600	
Labor Subtotal	$153,625	$40,825	$125,105	$58,705	$0	Labor Subtotal:		$378,260	
DIRECT COSTS									
Travel/per diem	$10,000	$5,000	$10,000	$0	$0			$25,000	
Supplies/Phone/Repro	$10,000	$7,000	$10,000	$0	$0			$27,000	
Equipment	$40,000	$20,000	$40,000	$10,000	$0			$110,000	
Sampling vessel	$50,000	$20,000	$50,000	$10,000	$0			$130,000	
Other	$5,000	$5,000	$5,000	$5,000	$0			$20,000	
Location control	$2,000	$2,000	$2,000	$0	$0			$6,000	
Direct Costs Subtotal	$117,000	$59,000	$117,000	$25,000	$0	Direct Subtotal:		$318,000	$318,000
						(add 8% to subs):		$0	
Task Total	$270,625	$99,825	$242,105	$83,705	$0		Total:	$696,260	$696,260
ANALYTICAL COSTS	No. of samples					Sum	Unit Cost	Total	
PCB congeners	600	60	200	0	0	860	$900	$774,000	
mercury	600	60	200	0	0	860	$200	$172,000	
%lipids	0	60	0	0	0	60	$50	$3,000	
TOC	0	0	200	0	0	200	$30	$6,000	
Grain Size	0	0	200	0	0	200	$150	$30,000	
DDE	0	0	200	0	0	200	$150	$30,000	
Conventionals	600	0	200	0	0	800	$100	$80,000	
Analytical Subtotal	$720,000	$69,000	$306,000	$0	$0			$1,095,000	$1,095,000
Task Total	$990,625	$168,825	$548,105	$83,705	$0		**TOTAL:**	**$1,791,260**	$1,791,260
						Cost per year:		**$358,252**	

Notes:
4) PCB congener analysis cost estimate from Triangle Lab ($500) and J. Amhrein of WDNR ($900)